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(Continued on 3rd Cover)

INDUSTRY PUBLISHERS LTD.,
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ELECTRO-PLATING IN PRACTICE

A practical Treatise comprising details of
Electroplating, Gold plating, Electro-
deposition of Silver, Nickel Plating,
Chromium Plating, Tin Plating,
Electro-galvanising, etc.

BY

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**AUTHOR OF DENTAL PREPARATIONS AND MANU-
FACTURE OF DISINFECTANTS AND ANTISEPTICS**

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CHAPTER I.

FUNDAMENTAL PRINCIPLES.

THE art of coating inferior metals with more costly ones has been in practice for a long time. It was found that copper ornaments or artistic goods tarnished when they came in contact with moist air. Iron articles were liable to similar corrosion and rusting. The earliest endeavours to rectify this defect found expression in imparting a thin coating on the metal. This not only prevented corrosion of the inferior metals but also lent them a more decent and costly appearance.

One of the greatest drawbacks in the old method was a lack of uniformity in the coating, which was thus liable to get scraped off at places. This defect has been completely remedied by the electroplating system which is easy to operate and is lasting in effect. According to this process deposition of copper, zinc, tin, silver, nickel, gold, etc becomes possible

The coating is not only lustrous and glossy but also uniform in depth showing the characteristics of the depositing metal on test. For example, silver ornaments when gold plated satisfy all the test of gold. In essence electroplating is now-a-days practised widely to cover up inferior metals with more costly metals,

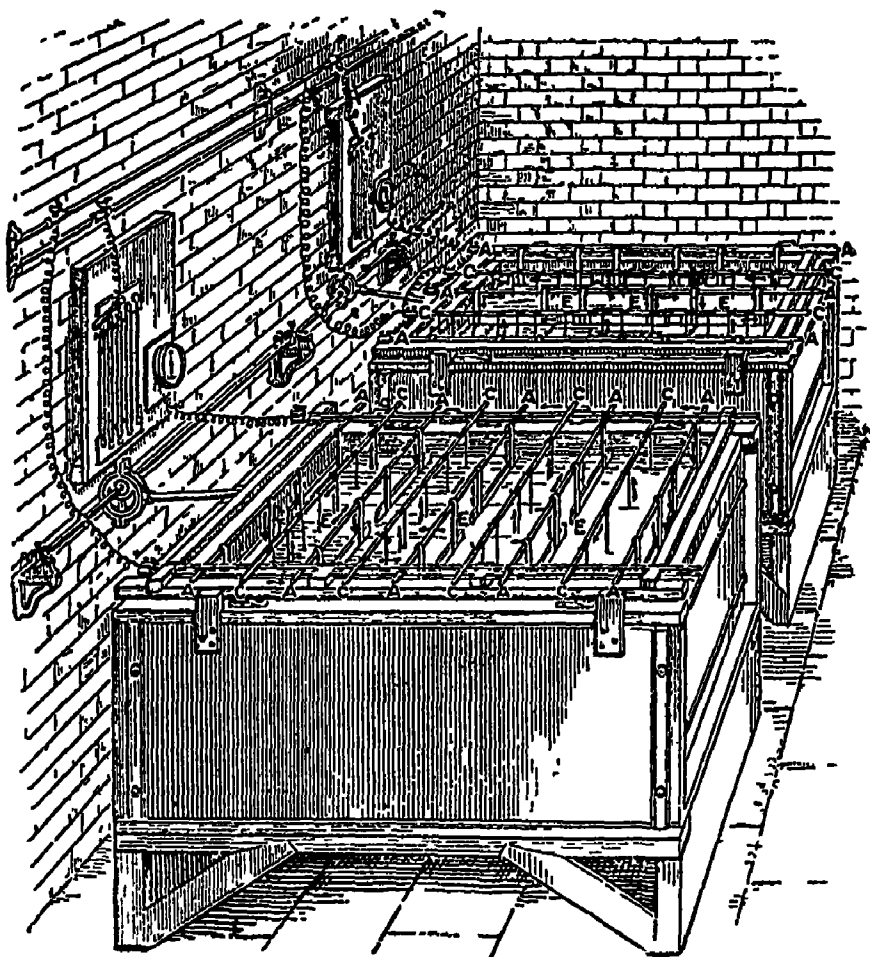


Fig 1 General Arrangement for Plating Vats

which improves the appearance and prevents chemical reaction from air at the same time.

WHAT IS ELECTRO-PLATING.

Electro-plating may be defined as the process of covering any electrically conducting material with an adherent and lasting film of metal, in a bath containing a solution of that metal, or its compound, by means of the electrolytic action induced by a current from a battery or dynamo. This technical definition may seem rather difficult for the average person to understand, but will be made plain as he proceeds step by step with the subject. In carrying out the operation successfully some knowledge of chemistry and electricity is necessary. The principal objects of electro-plating are to improve the appearance of the metal that receives the deposit and also to protect the plated metal from corrosion.

HOW METAL IS DEPOSITED.

For a beginner it is better to have a simple idea of what is happening in an electro-plating solution in order to appreciate the conditions which make for successful deposition.

In simple forms of electroplating apparatus the bath containing the metallic solution may itself form the battery, and metal is easily deposited in this manner. The more common and practical plan, however, is to obtain current from a source outside the bath, as from a regularly constructed electric battery or a dynamo.

When articles are to be electroplated, they are suspended by wires in the plating tank, which contains a solution of the metal which is to be deposited on them. From another wire is hung a piece of the same metal as that in the solution. The articles to be plated are connected by a wire to the negative pole of a battery and the metal plate is connected in the same way to the positive pole of the battery.

Now the metallic solution in the tank will conduct the electricity, and so a complete electric circuit is formed by which the current flows from the positive pole of the battery through the connecting wire to the metal plate. It flows through the solution to the article to be plated and thence back through the other wire to the negative pole of the battery—com-

pleting the circuit. Fig 2 shows the path of the current in an electroplating circuit.

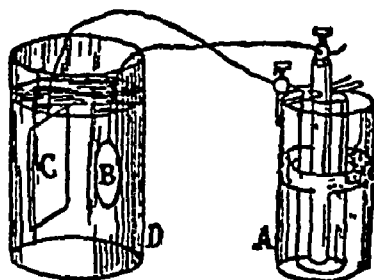


Fig 2 Connections for Electroplating

The metal plate attached to the positive pole of the battery is called the *anode* and the object to be plated in the tank is called *cathode*. By the action of the current particles of metal are attracted from the solution to the articles to be plated, and at the same time an equal amount of the same metal is thrown off the anode into the solution. Thus, although the solution is being constantly robbed of the metal, it is being fed at the same time, and so its strength is maintained. Of course, the anode plates must be of the same metal as that contained in the solution. The process by which the electric current affects the decomposition of the metal to be deposited on the articles to be plated is called *electrolysis*, being

governed by two laws which are discussed below. That part of the electrolyte which is liberated at the anode is called the *anion*, and that part liberated at the cathode, the *cation*. It does not necessarily follow that the *anion* and *cation* are actually given off as such at the anode and cathode respectively, for secondary chemical changes often take place between the ions and the *electrodes*, as the plates used to form the anode and cathode are called, or with the undecomposed portion of the electrolyte

LAWS OF ELECTROLYSIS

The two most important laws with which the electroplaters should be familiar in order to carry out their jobs efficiently are: Ohm's Law, Faraday's Laws and the Ionic Theory a fair knowledge of which enables him to form a mental picture of the mechanism of the electro-deposition process, and to account for the phenomena connected with it.

OHM'S LAW

This law and its applications are sufficiently familiar to all electro-platers and

students of electrical science It states that, in any electrical circuit

$$\text{Resistance (R)} = \frac{\text{Electromotive force (E)}}{\text{Current (C)}}$$

FARADAY'S LAWS

Law I The quantity of an electrolyte decomposed is proportional to the quantity of electricity which passes

Law II The mass of any ion liberated by a given quantity of electricity is proportional to the chemical equivalent weight of the ion

In the case of elementary ions the *chemical equivalent weight* is the atomic weight divided by the *valency* (combining power of an element with another element to form a compound), while that of a compound ion it is the molecular weight divided by the valency. If the weight of an ion liberated by the passage of the unit quantity of electricity is called the *electro-chemical equivalent* of the ion, then Faraday's laws can be put into the form:

(1) A definite quantity of electricity (coulombs), when passed through an electrolyte, does a certain, fixed, maximum amount of

chemical work In the case of a solution of a metallic salt, a definite quantity of electricity, when passed through the solution between two electrodes of the same metal as that contained in the solution, can cause a fixed, maximum amount of metal to be deposited at the cathode, and an equal amount to be dissolved at the anode The maximum amount of metal deposited or dissolved, at the cathode or anode, respectively, is fixed by the quantity of current passed.

Thus we have:—

Metal, deposited or dissolved, varies with the quantity of Electricity.

(2) If the same quantity of electricity is passed through the solutions of different metals, the amount of metals deposited stand to one another in the ratios of the equivalent weights of the metals Thus, suppose a quantity of electricity is passed through solutions of the metals, e g, Gold, Silver, Copper, etc (conveniently arranged in series) Then the maximum amounts of the metals obtainable may be expressed thus:

Weight of gold: weight of silver: weight of copper=Equivalent wt. of gold: Equivalent wt of silver· Equivalent wt of copper.

It follows from Faraday's Laws.—

That if the electro-chemical equivalent of any one ion is known, then that of the other can be calculated from the chemical equivalent weights. It is therefore important to determine the value of electro-chemical equivalent in the case of one ion. Accurate experiments have shown that when one coulomb of electricity passes, that is, when a current of one ampere passes for one second, the weight of silver deposited from a solution of a silver salt is 0.001118 gram. Since the atomic weight of silver is 107.88 and the valency, i.e., its combining power is 1, and the atomic weight of zinc is 65.36 and its valency is 2, hence the chemical equivalent of zinc is $\frac{65.36}{2}$ and the electro-chemical equivalent of zinc is $\frac{0.001118 \times 65.36}{107.88}$ or 0.000338 gram.

Hence a current of A amperes flowing for t seconds will liberate $0.000338 A t$ grams of zinc.

Since the passage of 1 coulomb will deposit .001118 gram of silver, it will require the passage of $\frac{107.88}{0.001118}$ coulombs or 96500 coulombs, to deposit 1 gram equivalent, that is, the chemical equivalent in grams of silver, that is, 107.88 grams of silver

Since the Electro-Chemical Equivalent (E.C.E.) is the amount of substance concerned with one coulomb, it is usually a very small amount. It is therefore expressed in milligrams. This amount multiplied by 3600 (seconds per hour) gives the weight of metal deposited per ampere hour, a useful figure in all computations of weights deposited. Further useful figures are the weights in pounds avoirdupois per 1,000 ampere hours, while, where we are concerned with estimations of thicknesses of deposits, it is easy to calculate the thickness of deposit for definite current densities and time.

The table reproduced here from "Electro-Plating" by *Field and Weill* will be of much value to electro-platers in calculating the thickness of the deposit.—

Element	Chemical Equivalent	E C E mg	Grms per amp hour	lbs (av) per 1000 amp hour
Cadmium	56	58	2 088	4 6
Chromium	8 75	091	3276	—
Copper (sulphate)	31 8	329	1 182	2 61
Copper (cyanide)	63 6	658	2 364	5 22
Gold (chloride)	65 6	676	2 436	78 oz troy
Gold (cyanide)	197	2 03	7 308	235 oz troy
Nickel	29 3	305	1 098	2 42
Silver	108	1 118	4 024	129 oz troy
Tin	57 5	615	2 21	4 87
Zinc	32 5	338	1 22	2 6

From the above table it will be found that to deposit 1/10 inch of copper with a current density of 20 amperes per square foot will require 89 hours

EVALUATION OF THE WORKING EFFICIENCY OF PLATING BATH

This is the second instance in which Faraday's laws are employed in workshop for general control purposes concerning the installation for this or that purpose of new solutions, previously unknown as regards their working properties and value. When a new solution is proposed as a substitute for one already in use, it is of the utmost importance to determine its efficiency first

The efficiency, as compared with the old solution, can clearly be determined by passing the same current for the same time through a small vat of each, the vats being connected together in series, and by weighing and comparing the weights of the deposits and the anode losses

EVALUATION OF THE ELECTRODE EFFICIENCIES

A certain definite and maximum amount of metal can be deposited (or dissolved) by a definite quantity of electricity. In most baths, less than the maximum is deposited; the nearer the maximum the amount deposited is, the greater the electrode efficiencies, and the better the bath. Thus, the amount of copper that can be deposited in a copper sulphate bath by 1 amp in 1 hour is 1.186 grms. If, on testing, the amount is found to be 1.1 grms only the cathode (or anode) efficiency equals

$$\frac{1.1}{1.186} \times 100 = 92.7 \text{ per cent}$$

LAWS OF ELECTRICAL RESISTANCE.

The *electrical resistance* of the conducting wire depends upon its (i) length, (ii) area of cross section, (iii) material of which it is made,

(iv) temperature, (v) molecular condition, density, purity, hardness, and other properties. The factors (i) to (iv) are the most important in electro-plating.

The relation between (i), (ii) and (iv) is given by the formula:

$$R = \frac{L}{A} T,$$

where R , L , A , and T denote resistance, length, area of cross section, and the specific resistance of the material, respectively. The *specific resistance* of any material is the resistance of a piece of 1 cm in length and 1 sq. cm in cross-section.

The effect of temperature upon resistance is different for metals and solutions. The resistance of a metal is increased by increase of temperature, while that of solutions is decreased. Hence, in electro-plating, hot metallic conductors hinder, while hot solutions favour the passage of electricity.

CURRENT DENSITY.

The rate at which metals are deposited is all-important, and these rates vary considerably. Some simple method of comparison is

desirable and even essential. The system adopted is usually the current (amperes) per unit area (sq ft.) This provides a simple method of indicating the current to be used Thus a current of 10 amperes on a surface of 4 sq ft means current density of $2\frac{1}{2}$ amperes per sq ft

POLARISATION.

This is a term frequently used in connection with electro-plating This expresses a phenomenon occurring in some electro-plating solutions This is due to anodes not dissolving correctly It also arises in some cases where the anode used is composed of another metal, and is quite insoluble in the electrolyte This reduces the strength of the solution appreciably within a very short time producing unsatisfactory deposition of metals But where soluble anodes are used this polarisation should not be present appreciably As soon as this will be detected, it should be rectified in order to ensure satisfactory results

PRACTICAL ELECTRICAL UNITS

The practical units employed in electro-plating are: the ampere, coulomb, ohm, volt, and watt

The AMPERE is the unit of current. It is that which is passing when 0.0011180 gram of silver is deposited in one second from a solution of silver nitrate in water.

The COULOMB is the unit of quantity of electricity. When the rate of flow of electricity is 1 ampere and the time of flow is 1 second the quantity of electricity that passes is 1 coulomb. Hence it follows that

$$\text{Coulombs} = \text{Amperes} \times \text{Seconds}$$

The OHM is the unit of electrical resistance, i.e., resistance to the passage of electricity.

The VOLT is the unit of electrical pressure or electro-motive force. It is the pressure required to cause a current of 1 ampere to flow through a conductor having a resistance of 1 ohm.

The WATT is the unit of power. When the electro-motive force of a circuit is 1 volt and the current passing is 1 ampere, the power in the circuit is 1 watt. 746 watts = 1 horsepower.

$$\text{Watts} = \text{Volts} \times \text{Amperes.}$$

CHAPTER II.

ELECTRICAL EQUIPMENTS.

ELECTRIC current used for electroplating is derived either from voltaic cells or from dynamos. If power is available, a dynamo is of course in the long run the most economical means of producing the electric current required for electroplating. But if a dynamo is out of question for want of power or on account of initial expense, its place can be satisfactorily filled up by batteries coupled together in sufficient number to produce the required current.

ELECTRIC BATTERIES.

An electric battery is composed of several cells, although a cell is sometimes called a battery. The cells are of various kinds, dry and wet, and the wet cells may be of single or double liquid.

With regard to the different kinds of cells, the *Smee* and *Wallaston*, and *Laclenche* are perhaps the most common types of single-

liquid cells, and the *Daniell*, *Bunsen*, and *Gravity* cells may be taken as representative patterns of double-liquid cells. The principle underlying each cell consists in the exciting of an electric current by the solution of the readily attacked metal, in conjunction with a metal or other element not so readily attacked, the effect being to set up an *electromotive force* that tends to produce a current of electricity around the circuit when a passage is completed for it outside the cell.

There are various objections to the use of primary batteries for electroplating. First, the current derived from them is not at all constant; secondly, the internal resistance of the battery increases, causing a gradual diminution of the current in the working circuit throughout the period of plating operation; thirdly, the high price of zinc and its excitants make them expensive; they require much time and labour for setting up and removing after the completion of operation; they give off fumes which are injurious to the health, unless they be placed by themselves in properly built and ventilated closets.

These adverse conditions, obtaining in the case of batteries, have resulted in the general adoption of suitable types of dynamos especially where the operations require a large and constant current

ARRANGEMENT OF BATTERIES

As the electromotive force (e m f) of primary batteries of standard size is small, it is of utmost importance to find out a suitable battery of larger E M F. This increase of voltage can only be possible by connecting the cells in series. This arrangement is shown in

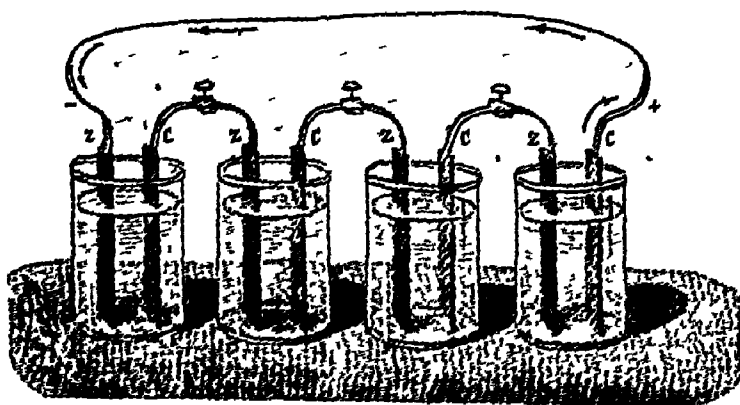


Fig 3 Cells in Series

Fig 3, where the positive of one cell is connected with the negative of the next, and so on, until the desired number of cells have been connected, and the final unconnected positive

and negative of the end cells form the terminals of the battery. The electromotive force (E M F) of such a battery is equal to the sum of the electro-motive forces of all the cells in the series. Usually only one kind of cell is thus connected to form a battery, and if so the E M F. of the battery is equal to that of one cell multiplied by the number of cells in the series.

Again, where greater amount of current is necessary several cells, instead of being connected in series, are connected in parallel as shown in Fig. 4. In this arrangement all the

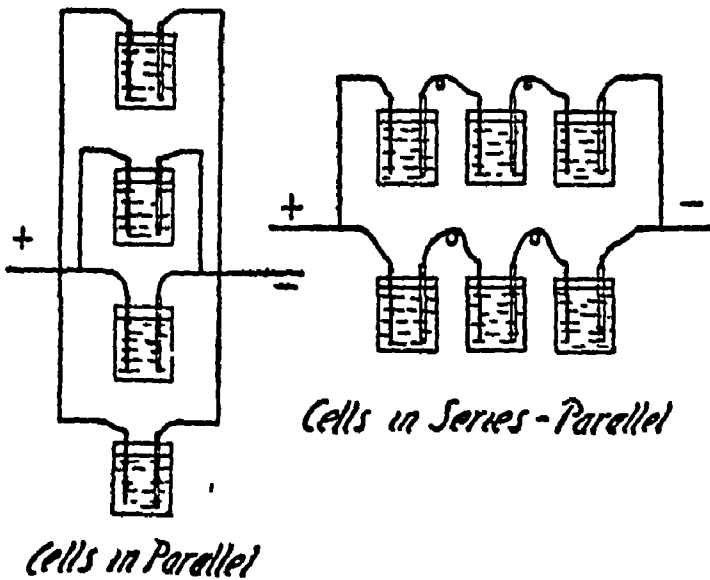


Fig 4 Cells in Parallel and Series Parallel

positives are joined together, forming the common positive terminal of the battery, and also

all the negatives are joined together, forming the common negative of the battery. The E M F of the battery thus connected is that of only one of the constituent cells, but it is capable of giving a current which is larger than one cell can give, in proportion to the number of cells thus connected in parallel.

Now where greater E M. F and larger amount of the current are required, the cells may be arranged partly in parallel and partly in series as shown in the above diagram.

DYNAMO

The advantages of employing a dynamo are that it supplies such a current which in every respect is suitable to the work of depositing metals. It is more cleanly in working, eliminates noxious gases, and is more easily managed. The best type of dynamo for the use of the electroplaters is some sort of shunt-wound or compound wound machine, giving a large volume of current at low voltage, the current being delivered constantly and in same direction. In the shunt-wound dynamo, there is automatically a continuous balancing of the

current as the load varies in the external circuit. The compound-wound machine, however, can also be designed to give a moderate volume of current at high voltage,

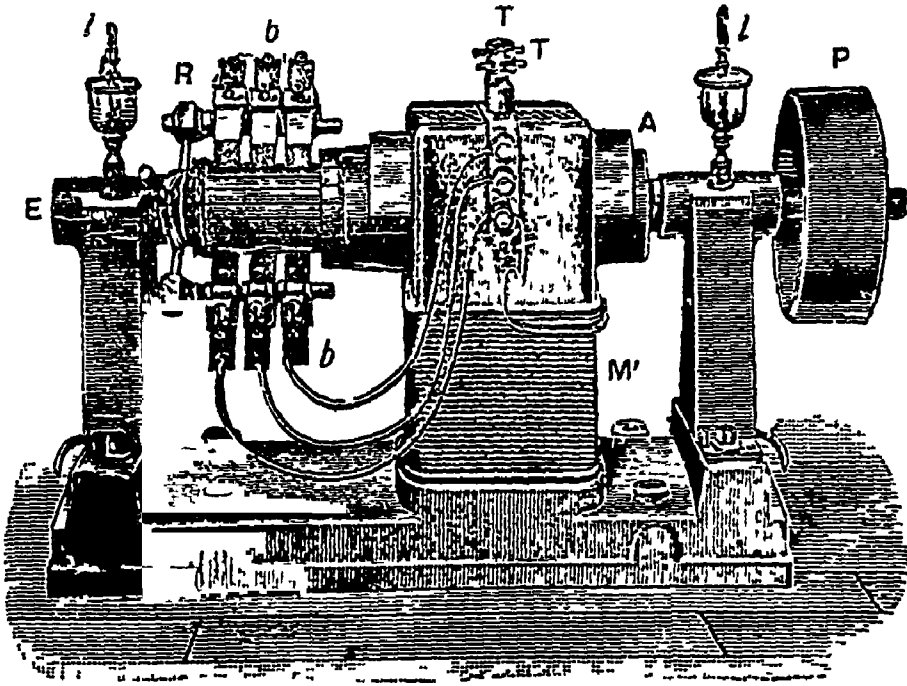


Fig 5 Plating Dynamo

and while a plating dynamo will generate high current at low voltage, say 10 volts

REGULATING AND MEASURING INSTRUMENTS.

1. RHEOSTATS

Rheostats are of the first importance in the plating room. Without them the varying degrees of current necessary for working

different kinds of solutions or for handling various sizes of baths cannot be obtained

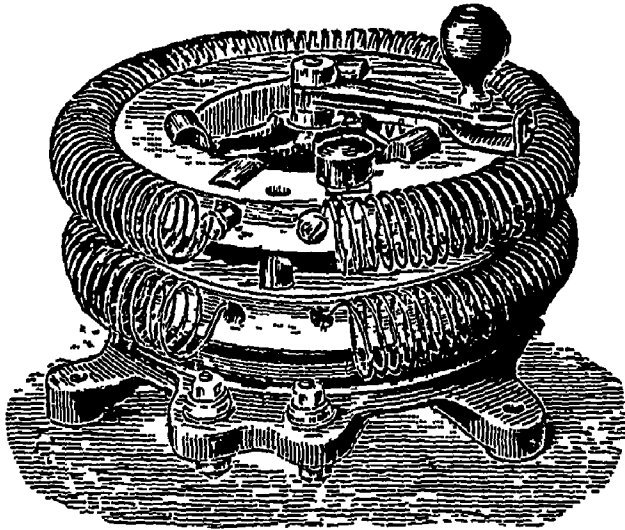


Fig 6 Series Rheostat

When the metals such as silver and copper, which require low resistance solutions, are to be deposited in connection with such metals as nickel and brass, which require high resistance solutions, a considerable drop in voltage is required for the former in order to prevent the blackening of the work

A rheostat inserted in the field of the dynamo will maintain an initial voltage on the whole system, but rheostats at each tank are necessary to further reduce the current to the proportions required by the solutions in those

tanks. While the field rheostat effects by setting a fixed resistance in the dynamo field,

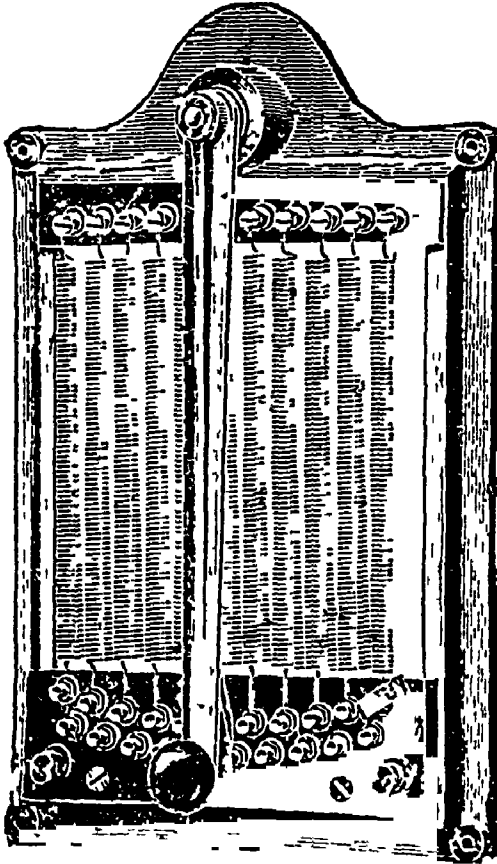


Fig 7 Parallel Rheostat.

it does not affect the amperage One style of rheostat is shown in Fig. 7 Throwing aside the technical terms, the rheostat is similar to a tap or valve in a water pipe, each wire taken in by it acting like the plug of a tap narrowing the orifice through which the liquid flows.

AMMETERS AND VOLTMETERS.

The ammeter measures the rate of current, in amperes. It is sometimes used in connection with the voltmeter.

The voltmeter is similar to the ammeter, but measures the voltage of the current.

Both ammeters and voltmeters are freely used in electroplating works, where the electrical energy is derived from some form of batteries.

METERS

Where strong electric current is employed, meters are used in place of ammeters so as to control the energy that is actually required for a particular case.

CHAPTER III.

PLATING ACCESSORIES.

IN the previous chapter we have considered with the electrical equipments necessary for the purpose of carrying out the plating operations. Now we shall consider the plating accessories, such as tanks, scouring trough, plating barrels, polishing lathes, brushes and other necessary machineries and instruments.

PLATING TANKS.

Most plating tanks are made of well seasoned wood, liquid-tight, and lined with some suitable material which will not be acted upon by the solution the tank is intended to contain.

As for instance: the tanks for holding gold plating solutions should be impervious to the action of potassium cyanide at a temperature of 150° to 180°F. Tank for nickel plating solutions and other solutions of low acidity should be lined with a mixture of asphaltum and pitch. For acid copper solu-

tions, steel or wooden tanks lined with lead are satisfactory. Cyanide of copper solutions are best kept in steel tanks, wood being unsatisfactory on account of the action of the alkali

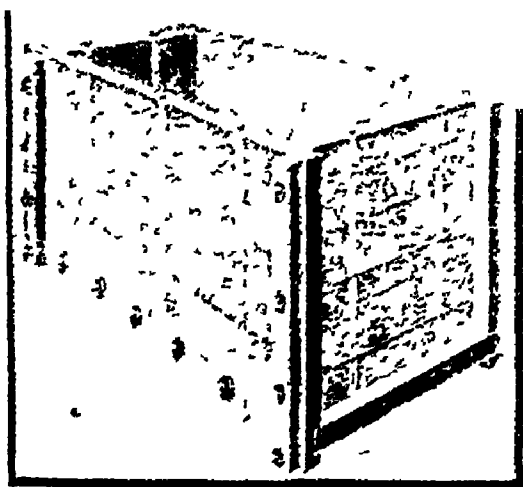


Fig 8 Plating Tank

on the wood. Steel tanks lined with antimonial lead are likewise used for chromium plating.

PICKLING TANKS

Since acid pickling solutions can be kept most satisfactorily in earthenware containers or in wooden tanks lined with asphalt, or in rubber-lined steel tanks, all plating shops should possess several such pickling tanks.

PLATING BARREL

The cheapening in the cost of plating has been so marked that mechanical electroplating apparatus is shown in Fig 9. It consists of a barrel in which are placed the articles to be plated. The barrel is so constructed that it may be revolved by belt device over two pulleys to provide two kinds of speed. The

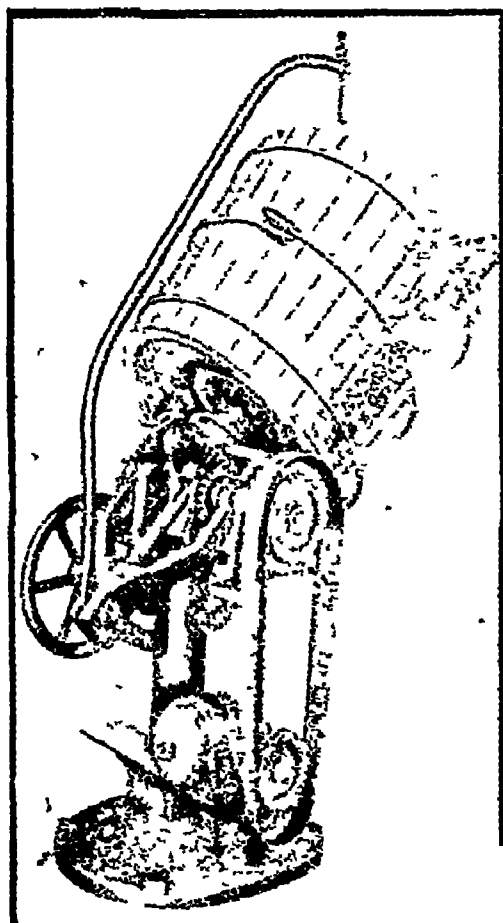


Fig 9 Plating Barrel

barrel is removable at any time without interfering with the device. The cathodes are made curved to fit the periphery of the revolving barrel, and when the anodes are hung at each side of the tank, the work is always equidistant from the anodes, thereby insuring uniform deposit over the surface of the articles.

SCOURING, SWILLING AND RINSING TROUGHS

These troughs may be made large or small, according to the size of the shop. Generally this is made in shape like the ordinary stationary wash tub, and should be of heavy dressed plank, well matched and jointed. As strong potash solutions are used in scrubbing, the trough or tray is sometimes painted with prepared asphaltum, or lined with lead, the seams of which must be wiped and not soldered. Sometimes the troughs are divided in the middle by a partition, one part being used for scouring and the other for holding clean water for rinsing the articles after they have been scoured clean.

SCOURING BRUSHES

Brushes are made in many patterns and sizes suitable for different kinds of work.

Brushes made of cotton and other vegetable fibre are commonly known as potash brushes. They are used for cleaning work requiring strong alkaline solutions for removing grease. Brushes made of animal fibre cannot be used for this work as they would soon wear away under the dissolving action of the potash.

Other useful forms of brush are the horse hair sawdust brush, wire foundry brushes, cup shaped brushes of wire or bristles, and steel wire scratch brushes.

DIPPING VESSELS

These are employed for holding the articles for dipping them into the various solutions used in cleaning the articles preparatory to the plating. All dipping vessels used in acid solutions should be made of vitrified or glazed stoneware or glass or aluminium.

TUMBLING OR RATTLING BARRELS

Small objects, such as castings, stampings, etc. are best cleaned by tumbling or rattling. By the help of these barrels large quantities of work are thus easily and cheaply cleaned.

without much manual labour. If rough castings are being worked, the sand, scale, etc., adhering to them is allowed to remain in the barrel, where it acts as a polishing powder, brightening the parts which are not reached by the metal or other castings; but when tumbling for a bright finish is to be performed, sand, dirt, etc. are exhausted by means of the blower, so that the surfaces are finely polished by friction only—burnished, as it were, by rubbing against other metal of the same kind. A strong exhaust should be kept up when polishing in this way, or the finish will be dead instead of bright.

A tumbling barrel has generally got a convex head for dry tumbling. This type of barrel is essentially adapted for removing burrs and for smoothing small castings by giving them automatically three distinct motions, viz., rolling, shaking and spreading.

STEEL BALL BURNING BARRELS.

Burnishing with steel ball is done both on small articles preparatory to plating and also articles that have been plated and require a highly burnished finish. This machine is in-

tended for sand and water grinding, washing out core sand, etc. The barrel is provided with a gland for connecting a water pipe to supply a constant flow of water. This machine consists of an iron barrel mounted horizontally and is almost filled with steel balls. The barrel is mounted in such a way that it can be made to rotate on its axis horizontally. The articles to be burnished are placed inside the barrel and the steel balls are allowed to slide in and out of the crevices, angles, and curves, so as to give the parts a higher lustre than that obtained by any other method.

GRINDING AND POLISHING MACHINES

These machines consist of a stand carrying a small pulley between two bearings with shaft extended at each end to take the various buffing, polishing, and grinding wheels, brushes, etc. A type of polishing and buffing machine suitable for both light and heavy work is generally used.

POLISHING WHEELS.

The cleaning, polishing and buffing wheels required by electro-platers are the following:

Felt wheel, leather wheel, emery or carborundum wheel, cotton and flannel buffs, long thin felt buff for the inside of finger rings, and brasswire scratch wheel.

Rough heavy castings are first ground upon coarse solid emery or carborundum wheels, usually run at a slow speed. After this the articles are polished with different polished wheels according to requirement

OTHER USEFUL APPLIANCES

Besides the above, the following accessories are indispensable for a plating shop: (i) Brass rods, which are laid on insulators fixed on the frame of the bath; (ii) Rod connections, which enable the rods to be connected together; (iii) Anodes; (iv) Flat metallic strips; (v) Good scales; (vi) A clock, (vii) Several galvanised iron pails, wooden buckets, various wood-fibre brushes, a glass funnel and graduated glass, thermometer, hydrometer, etc

POLISHING MATERIALS.

The following are used with satisfaction: Pumice powder, Tripoli powder, emery, silver sand, rouge, rotten stone, whiting, etc

CHAPTER IV.

CLEANING THE ARTICLES.

METALLIC articles are generally covered with grease, dirt, oxides (scale and rust), and the liquids from vats through which the work has passed on its way to the plating work. Hence their complete removal is indispensable for the success of the process.

If the surface of the article is not thoroughly clean, the deposit will not perfectly adhere. By the word *clean* is meant—not clean to the eye merely, but *chemically* clean whereby an entirely unobstructed surface of metal must be exposed to the solution to insure the thorough adhesion of the particles of metal to the cathode (or goods to be plated in the tank). It is necessary, therefore, to free the surface of the goods, including every line and indentation, from every trace of foreign matter of any kind, whether in the form of rust, verdigris, tarnish, or any other kind of corrosion, or in the form of oil, grease, lacquer,

sweat, etc. The touch of a finger on the prepared surface is sufficient, for instance, in silver-plating, to cause the silver to strip off from the spot when the scratch brush or the burnisher is applied.

The operator must also see that all deep scratches, dents and cracks are removed before the goods are put in the tanks, and that all necessary repairs are made, avoiding an excess of solder, and that all previous coats of silver or nickel are removed and the surface polished.

CLEANSING SOLUTIONS

To remove grease, etc., first plunge the goods in hot lye, using $\frac{1}{2}$ pound of caustic potash or soda to 2 gallons of water, then plunge them in hot water and give a final rinsing in cold water, when they are ready to be treated for rust and corrosion. If there is no coil, the lye and water kettles may be firmly set over a gas furnace.

Rust, verdigris and other metal oxides are removed by a pickle of a dilute mineral acid. A mixture of equal parts of sulphuric acid and water makes a good cleaning bath for these oxides. String the articles on a wire and

plunge them in the mixture for a few minutes. Use the scratch brush and wash, and if the stain is not removed, repeat the process.

The light tarnish may be removed by dipping in a strong solution of cyanide of potassium, say, 2 ounces of cyanide to 1 gallon of water, with the addition of a few drops of liquid ammonia. For the oxides of copper and zinc, use a mixture of 1 part of sulphuric acid in 20 parts of water, and if the stains are deep and fail to come off, strengthen the pickle.

For rust on iron or steel, use a pickle of 6 parts of sulphuric acid, 1 part by hydrochloric acid, and 160 parts of water. The articles are dipped in this solution for 15 to 30 seconds or longer if necessary. For oxides of lead and tin, including britannia ware, pewter, etc use a hot lye solution.

Lacquered goods should be steeped for a few minutes in a hot alkali solution. They should then be well brushed with an old scratch-brush and rinsed in hot water.

The next process after cleaning, if the job is one of replating silver, is to remove all the

old silver plate. For this purpose a stripping solution, made as follows, is used.

STRIPPING SOLUTION.

To one gallon of commercial sulphuric acid, add 12 ounces of potassium nitrate (salt-petre) and heat to 150°Fahr. Do not put soft metal, such as britannia, lead, pewter, tin, zinc, etc., in this solution or any wet articles, as they would be eaten by the acid. Fifteen minutes is usually long enough to leave the goods in this pickle. After the old plating is removed, the surfaces of the articles to be plated should be well brushed in water with a stiff brush to remove loosened dirt from crevices. This process may reveal several imperfections in the way of dents and scratches which should be taken out on the polishing lathe or by the careful use of the hammer. After polishing, the articles should be again plunged into the alkali pickle to remove the film of grease which was put on in handling. The dipping, however, adds a thin coat of black oxide, which must be removed by bright dipping or scouring. For this purpose the article is held on the dipping tray with the left

hand, while the article is brushed with a wet brush dipped in pumice powder until every trace of oxide is removed. Then rinse in water, and it will be quite clean and ready for the plating tank.

But in spite of every possible precaution the articles are liable to be exposed to the atmosphere for a few seconds. This produces a thin naked film of oxide over the surface of the metal. Although this film is quite imperceptible to the eye, it is quite sufficient to prevent perfect contact between the deposited metal and that of which the article is composed. This produces a great deal of trouble among the platers because the articles after being coated with metal are frequently liable to strip under the pressure of the burnisher. To overcome this difficulty, and to secure a perfect adhesion of the two metals, a third metal (mercury) which has the power of alloying with the others is used.

After this treatment the article should not be touched again with the hand, but should be picked up with a wire hook; if it is to be silverplated, it is dipped into the necessary bath,

again rinsed in clear water, and put into the plating tank.

If the goods are of iron, steel or zinc, they should be copper-plated before the silver is put on. Many platers do this with soft metal goods also, getting a better job by this process

QUICKING PROCESS.

Since this process of "quicking" is indispensable to platers it will not be out of place to describe it here in detail

Put an ounce of mercury into a glass flask, and pour in an ounce of pure nitric acid diluted with three times its bulk of distilled water. If after the chemical action, it is found that there is left a small amount of undissolved mercury, add a little more acid, applying gentle heat, until the whole is dissolved. The solution is then poured into a gallon of water, and well mixed by stirring. The solution is then ready for use and is termed the *quicking solution*, or mercury dip. Articles of brass, copper, or German silver, dipped into this solution, at once become coated with a thin bright film of mercury.

ELECTRO CHEMICAL CLEANING PROCESS.

This is the latest development in the cleaning process. It consists in removing by means of the electric current such materials as exist on the surface of the work. For this purpose the work is suspended from the anode or cathode of a vat, put together in all respects as a plating tank, but having as liquid contact a solution of some chemical, such as an acid, or cyanide, or potash, which, in solution, is a good conductor of electricity. Whether the solution is an acid or an alkali depends upon the work required to be done. Removal of scale and thick rust is effected in an acid solution, for removal of a thin layer of rust, or of grease, and sometimes, of tarnish, an alkaline solution is used. A heavy current is then passed through the solution for 10 to 15 minutes by which time the whole of the impurities are dissolved out, leaving the surface of the work bright and clear.

MECHANICAL CLEANING

Mechanical scouring is employed as an aid to both chemical and electro-chemical cleaning. The articles must, first, be washed

with caustic potash to remove grease and then it is immersed in acid dip. After remaining in this for a while the article is removed and rinsed. The article is now brushed with a bristle brush that has been rubbed in powdered pumice so as to remove all deleterious materials from the surface.

Instead of cleaning the article by rubbing with brush it may be placed in a rattling drum already described. It is kept in motion whereby it is cleaned and polished within a few seconds.

CHAPTER V.

PLATING SOLUTIONS IN GENERAL.

AFTER dealing with various processes of cleaning metals, we come to describe the essential requirements of good plating solution and the functions it plays in producing a satisfactory metal deposit

A good electro-plating solution therefore must contain a representative from one or more of the following classes of substances:

- (i) A salt containing the metal to be deposited;
- (ii) Conducting salt (so-called), among which are included acids, which are often regarded by chemists as salts of hydrogen; and (iii) Addition agents

METAL CONTENT.

The metal-containing salt used as a constituent of a plating solution is usually either the sulphate, e g, copper sulphate, zinc sulphate, iron sulphate, and so on, or the double cyanide, e g, gold potassium cyanide, silver potassium cyanide, or copper potassium

cyanide. Sometimes, though much less frequently, some other salt is employed. For instance, zinc chloride is used in some zinc baths; lead acetate is used in lead baths, and tartrates, fluosilicates are occasionally used. The sulphate is much to be preferred since it is usually cheaper, and it is easy to control over the working of the bath.

CONDUCTING SALTS

Metallic compounds, however, are not usually good conductors, and the addition of other salts which, freely dissociating, contribute to conductance, is essential to many solutions. A very wide choice is available, and many sulphates and chlorides have been applied to this purpose. Other properties also determine the choice. Where possible, the mineral acids are employed because they provide hydrogen ions which migrate rapidly and thus make an important contribution to the conducting power. Where these stronger acids are not permissible to any extent, as, for example, in the acid baths for nickel, iron, cobalt and zinc, neutral salts must be employed. Of the sulphates, those of sodium, potassium,

ammonium and even magnesium have been used. Chlorides, as those of sodium and ammonium, are frequent additions. These salts offer other advantages upon which their selection must finally rest.

ADDITION AGENTS

Addition agent is the term by which a large number of substances are known in the electro-metallurgical world. Their function is similar to that of the conducting salt. When present in the solution they regulate the deposit, otherwise the grains of the deposit obtained would be non-coherent and the deposit would then be useless for practical purposes.

Addition agents frequently used are gum, sugar, dextrose, olive oil, and the like. Among other substances that have been employed are: naphthalene sulphonic acid, pyrogallol, resorcinol, glycerine, liquorice extract, eiconogen, and very many others. It is not always the case that the addition of an addition agent taken at random will produce the desired result: the particular substance to use in any particular case has to be found by trial.

COMPOSITION OF PLATING SOLUTION.

The composition of the plating solution should therefore be as simple as possible because the simpler its composition is, the easier it will be to work and control. It is only rarely that a solution cannot be devised that contains only three components at most. As regards the conducting salt employed, this should, if possible, contain the same acid radical as does the salt containing the metal. Thus sulphuric acid, and not nitric acid, should be used in the acidified copper bath; ammonium sulphate, and not the chloride is used, as a rule, in the nickel sulphate bath; and so on. The result of observing this rule is that the number of different anions discharged at the anode is lessened; consequently the knowledge of what is happening at the anode is more certain, and a better control can be maintained over the general working of the bath. A solution containing half a dozen components gives a lot of trouble to the operator.

SOME TYPICAL RECIPES.

GOLD PLATING.

Gold " 10 parts.

Ammonia (sp. gr. 0.88)	50	parts
Potassium cyanide	27	„
Distilled water	1000	„

The gold is dissolved in aqua regia (1 part nitric acid and 3 parts hydrochloric acid) using heat; the solution containing chloride of gold, is precipitated with ammonia—carefully and till no further precipitate is formed; the precipitate is then filtered and washed, but on no account allowed to become dry; the washed precipitate is then dissolved in the cyanide of potassium

The preparation of gold solution is a matter for skilled and careful work. The employment of pure gold salts ready for use is recommended but in a big plating establishment where the consumption is rather high, it would be more economical to prepare the gold salts for own use.

SILVER PLATING.

For Heavy Deposit.

Silver cyanide	3	oz.
Potassium cyanide	2	oz.
Distilled water	1	gallon.

For Light Deposit:

Silver cyanide	$1\frac{1}{2}$ oz.
Potassium cyanide	$1\frac{1}{4}$ oz.
Distilled water	1 gallon.

COPPER PLATING.

For Heavy Deposit.

Copper sulphate	$2\frac{1}{8}$ lbs.
Potash alum	2 oz.
Sulphuric acid (pure)	5 fl. oz.
Distilled water	1 gallon.

For Light Deposit.

Cupro-Cupric sulphite (Chevreul's salt)	$4\frac{1}{2}$ oz.
Potassium cyanide	7 oz.
Distilled water	1 gallon.

NICKEL PLATING

For ordinary work.

Nickel sulphate	3 lbs.
Sodium chloride	$\frac{1}{2}$ oz.
Boric acid	1 oz.
Distilled water	1 gallon.

For heavy deposit.

Nickel sulphate	3 lbs.
Magnesium sulphate	8 oz.
Boric acid	3 oz.
Distilled water	1 gallon.

For Barrel Plating.

Nickel sulphate	3½ lbs
Common salt	1 oz.
Boric acid	3 oz
Distilled water	1 gallon.

ZINC PLATING.

Zinc sulphate	3 lbs.
Common salt	2 oz
Boric acid	3 oz
Aluminium sulphate	3 oz.
Dextrin	1½ oz.
Distilled water	1 gallon.

BRASS PLATING.

For ordinary work.

Potassium cyanide	16 oz
Copper carbonate	8 oz
Zinc carbonate	2 oz.
Sodium carbonate	2 oz.
Sodium bisulphite	3 oz
Distilled water	1 gallon.

For Barrel Plating.

Potassium cyanide	15 oz
Copper carbonate	5 oz.
Zinc carbonate	1½ oz
Sodium bicarbonate	2 oz
Sodium bisulphite	½ oz.
Distilled water	1 gallon.

IRON PLATING.

Ferrous chloride	16 oz.
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Calcium chloride (anhydrous)	18 oz.
Distilled water	1 gallon

LEAD PLATING.

Lead perchlorate	1 lb
Perchloric acid	$\frac{1}{2}$ lb
Peptone	$\frac{1}{6}$ oz
Distilled water	1 gallon

TIN PLATING.

Protochloride of tin	1 lb.
Caustic soda	$\frac{1}{2}$ lb
Distilled water	1 gallon.

CHROMIUM PLATING

No formula can be recommended to the general plater

CADMIUM PLATING

Cadmium potassium cyanide	12 oz.
Caustic soda	$\frac{3}{4}$ oz.
Dextrin	$\frac{1}{4}$ oz.
Distilled water	1 gallon

PREPARATION OF PLATING SOLUTIONS

In preparing plating solution dismantle and thoroughly clean the plating vat; if this is of wood and old, renew the match-board lining. Half fill the vat with water, and place the filter-frame on the vat. Half fill the enamelled iron vessel with water, and heat nearly to

boiling. Then dissolve in the water enough of one or other of the soluble components of the bath, e.g., the nickel sulphate, to make a saturated solution. Stir well and continue heating, in order to dissolve quickly. Transfer the solution to the vat by means of bucket and hand-bowl, pouring it on to the filter, and stirring the liquid in the vat. Repeat this process until all the soluble salts are disposed of.

* In cases where salts insoluble in water are components, e.g., copper carbonate or silver cyanide, dissolve some of their solvent, e.g., potassium cyanide in the hot water in an enamelled iron vessel; add, gradually and continually stirring, as much of the metal-containing salt as the solvent will dissolve, allow to settle; and remove the clear solution to the vat.

When all the salts are dissolved, add the water necessary to make the required amount of solution, stir the whole well, and allow to cool.

THROWING POWER OF SOLUTION.

When a metal of irregular shape is being plated, the parts near the anode (positive pole) will be plated more heavily than will those

farther away because, there will be less resistance to the parts nearer to positive than the parts far away from it. It has been noticed that in many electroplating operations this tendency toward uneven deposition is counteracted by other factors in favour of a more uniform distribution. A solution in which conditions are such as to correct to a fair extent such uneven distribution as would be obtained if Ohm's law were entirely applicable is said to have *good throwing power*. One in which the distribution is that predicted by calculation is said to have no throwing power. Some solutions, like chromium-plating solutions, have, technically speaking, a negative throwing power.

When a point on the cathode relatively near to the anode receives a greater current density than the other parts there is soon a greater reduction in metal ions at that point. This causes polarization, which produces a local back E M F having the same effect as if the resistance were increased between the anode and the near point of the cathode. Consequently, the more remote parts receive more

current than they would otherwise, in other words, the throwing power has been improved. If such polarization did not exist, the near point on the cathode would grow rapidly, every bit of metal deposited would aggravate the matter, and *treemng* would result. In solutions with high conductance, the relative effect of polarization is more pronounced, so that high conductance is said to improve the throwing power.

Warming the solution also improves the conductance, but it reduces the effect of polarization still more, so that generally an elevation in temperature decreases the throwing power.

ANODE AND CATHODE EFFICIENCIES

In all really good solutions the efficiencies of anode and cathode will be approximately 100 per cent. Usually the efficiency of anode is lower than that at the cathode, and this means that the metal is taken out of the solution faster than it is supplied to it. It means, too, that the bath will gradually become poor in metal, and this must be supplied from outside (e g, by addition of metal salts)

GENERAL CHARACTERS OF DEPOSITS

A good solution should give a deposit that possesses certain characteristics. The deposit should be close grained. It should be matt and non-crystalline in appearance. It should be light in colour; but it ought not to be bright. A bright deposit is almost always hard and brittle. The bath should be capable of continuously yielding a deposit having the required qualities over a considerable length of time, that is to say, for 3 or 4 hours at least. A competent plater knows that his deposit is a good one if it is of good colour, smooth, dull, and non-crystalline (to the eye), and if any outgrowth that forms on the edges of the articles is rounded in appearance. Another characteristic of a good solution is that it will give a result that is approximately the same thickness all over the surface of the articles. Owing to the way in which the current is distributed over the surface of a cathode, the thickness of the deposit will never be everywhere the same. The deposit on re-entrant parts of the surface will, usually, be least, and that on corners and edges most. The lines of

force between an anode and a cathode are distributed in exactly the same way as they would be between two metal conductors in air, or as they are in magnetic field. Consequently, the current density will always vary over the area of a cathode (or anode), and since thickness of deposit varies with the current density, that thickness will not be uniform. Nevertheless in all good solutions the conductivity will be good, and hence the thickness will not vary considerably.

CHAPTER VI.

HOW TO OBTAIN A GOOD DEPOSIT.

WITH the principles set out in the last chapter in mind, anyone can control his solutions much more effectively than if he does not know them. There are, too, a number of practical rules which have to be observed in order to obtain the best results and avoid troubles

(a) *Cleanliness should be made a fetish*
All rods and vats and anode connections should be cleaned at least daily. Meters must be cared for; and the wires of the resistance boards must not be overloaded

(b) *Nothing should ever be suspended in a solution unless the current is passing.* In the case of some kinds of solution (nickel and iron, for instance), if the work is in the vat and no current is flowing, slight oxidation will occur, any deposit formed on an oxidised surface has every chance of peeling off. In the cases of other solutions, e.g., cyanide baths (copper and silver), the metal of which the

work consists—say, copper or German silver—will dissolve if no current flows. Hence, all articles accidentally dropped into the solution should be at once removed.

(c) *Good, sound anodes should always be employed*—anodes consisting of cast metal rather than those made of rolled metal. As a general rule, as many anodes should be used as can be conveniently suspended from the positive rods. There is no economy in using poor or an insufficient number of anodes. The current has to get into the solution by way of the anodes, and the bath should be able to get as much of its metal as possible from the anodes. It follows that anodes must be cleaned down to the solid metal every day, for if the surface is not clean it cannot be attacked and dissolved, and, moreover, if the anode surface has a layer of oxide or of decomposition products upon it, there will be a layer of non-conducting material which will hinder the free passage of the current.

(d) *The practice of using two cathodes within two anode rods is to be condemned.* The result of so doing is that, when the vat is

loaded there will be two rows of work between two rows of anodes. Thus, only one side of the work is opposed to the anodes, the other side will be screened by the articles composing the other row of work. Comparatively little current will find its way between the articles of the one row to the inside surfaces of those of the other, and consequently these will receive relatively little deposit. The plated articles when finished will show many defects.

(e) *The upkeep of the solution* The rules of practice regarding the maintenance of the solution are of the greatest importance. In no case the strength of the solution should be allowed to decrease. This must be done by the addition of compound in the form of solution from time to time. But the amount of salts that need to be added should be definitely calculated beforehand. Of course, this addition of salts to plating solution is never looked upon as a good one but it is often found necessary to add resort to this method in practice.

(f) *Agitation* In the majority of cases it is advisable to provide either for agitation

of the solution or movement of the articles while deposition proceeds. The advantages to be gained thereby are as follows:—(1) The liquid at the surface of the work will be continuously renewed. (2) Several renewal will allow of the employment of a higher current density. (3) Greater output will be obtained in consequence of faster work. (4) The structure of the deposits will be more uniform, and the solution will be maintained more uniform in composition, and stratification, due to the formation of layers of liquid of different composition, will be prevented.

(g) *Drying out* This operation comes between the deposition process proper and the finishing of the work. When the deposition is finished, the article is removed from the plating solution, and should be well swilled in clean, running water (cold), and then in hot (nearly boiling) water. After passing through the hot water swill, the work is either put aside to cool and complete drying, or the drying is completed by rubbing the work with hot sawdust. The process of *drying out* would not have been mentioned here if it were not that trouble may

arise owing to defective plating, known to platers as *spotting out*. This *spotting out* is due to insufficient swilling and drying, articles made of cast metal are especially troublesome in this respect, and particularly so when they have been plated in the copper cyanide or brass solution. If the solution that has found its way into the pores of the metal is not got rid of during the *drying out* process, it will be sure to make its presence known sooner or later. Round spots appear on the surface of the deposit wherever this has a hole in it, and and the liquid that oozes from the hole will corrode the deposit

CHAPTER VII.

OUTLINE OF THE WHOLE ELECTRO-PLATING PROCESS.

BEFORE using the tanks for holding plating solution, they should be well rinsed with clean water. For this purpose they are filled with water and kept aside for several hours. By this time the tanks should be examined whether there is any leakage or not. They are then emptied and plating solution is poured in. Now the conducting rods, which usually consist of brass tubes with a core of iron rods, are laid across the bath, lengthwise. Their number would be three or five according to requirements. If three rods are to be used, the two extremes should be employed for suspending the anodes, while the middle one for suspending the articles to be plated.

The articles having been cleaned by the methods already dealt with in a special section of the book, are suspended by wires in the plating tank, which contains a solution of the metal which is to be deposited on them. From

another wire is hung a piece of the same metal as that in the solution. The articles to be plated are connected by a wire to the negative pole of a battery and the metal plate is connected in the same way to its positive pole.

To give a good idea, the general prospective view of two vats in a plating shop is shown in Fig. 1. These vats are seen to be arranged in parallel, with the ampere-meters and regulating resistances (rheostats) in circuit and a shaft along the side of each vat which, by means of eccentrics, moves an oscillating frame, causing the work to constantly keep in gentle movement, a movement which is found to be very conducive to uniform plating 'deposits'. "A" shown in the diagram are the anode rods and "C" the cathodes.

It need hardly be said that these vats are intended for nickel, copper, or silverplating, but not for gold work, which is done in much smaller vats, usually of stoneware or china.

In setting up and operating connect the anode rods to the positive wire of the main line, and the cathode rods to the negative wire.

MOVING THE ARTICLES WHILE IN THE BATH

In order to attain uniformity of deposit upon the articles it has been found necessary to keep them slowly in motion; because the deposition commences from the extreme end of the article in solution and this progresses in the same ratio during the whole time, the articles receiving the deposited metal provided the solution and the work remain undisturbed

There are several ingenious devices adopted for this purpose, to several of which we may now direct attention

To keep the articles in gentle motion while in the bath, one method is to connect the suspending rods to a frame of iron, providing with small wheels, which travel to and fro upon the inclined rails attached to the upper edges of the tank. This motion, both horizontal and vertical, is given by means of an eccentric wheel driven by some sort of energy. By another arrangement, the articles are suspended from a frame, and the motion is given by an eccentric wheel so that the articles can be moved to and fro producing uniformity in the deposit

PLATING SMALL ARTICLES.

Where a large number of small articles are to be electroplated, the time required in stringing them on wire for hanging in the tank becomes a considerable item To do away with

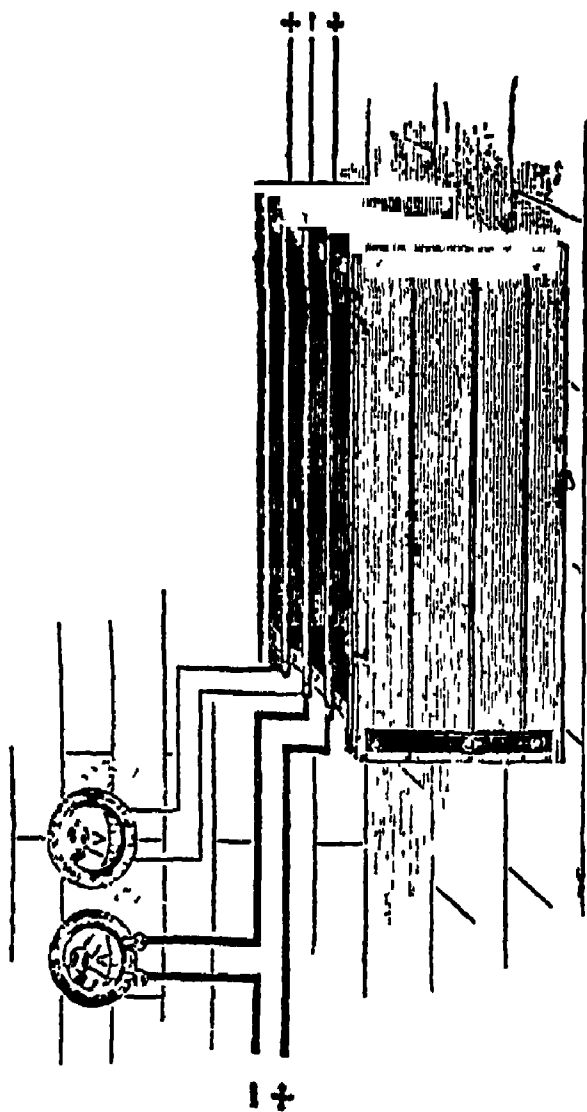


Fig 10 Connections of Voltmeter, Ammeter and Vats to the Dynamo

this expense, a special tank has been brought out. This tank has a perforated cylinder in which a large number of small articles may be placed and which is kept in constant rotation by a belt.

The articles to be plated are poured into the cylinder as shown in Fig 9, and the anodes of copper, nickel, or whatever the coating is to be, are hung in parallel rows on each side of the cylinder. The cylinder should be rotated at from 10 to 20 revolutions per minute, two speeds usually being provided for by a stepped pulley outside the tank. Special carved anodes are used, making the operation quick and effective. It is connected to the positive wire of the main line, and the cathode rod to the negative wire. Then a rheostat tank and the main line and electric current is allowed to pass through the plating solution. The cylinder at the same time is rotated so as to ensure a regular deposit. When the desired amount of coating is obtained the articles are taken out and submitted to the finishing operation, without which the articles will present a dull appearance.

FINISHING PROCESS

Electro-deposits are usually dull in aspect, and possess little or no metallic lustre. The process of producing the appearance which the goods have when they come on to the market is called finishing. This is effected by means of *mops* and *compos*. A mop consists of a number of circular pieces of linen or calico, fastened together by a leather centre. Sometimes the layers are stitched together, sometimes they are open. Compo consists of polishing material (tripoli, lime, or rouge), and a binder (stearine, wax, or other similar material). Compos are usually put up in the form of bars. To finish an article, the mop of convenient diameter is set on the threaded end of a spindle which can be rotated by means of a belt or motor; the bar of compo to be used is pressed against the rotating mop in order to supply this with the polishing material and the deposit then polished. When the polish has been obtained, it is advisable to bring up the colour by pressing a bar of chalk against the rotating mop, and then lightly mopping the deposit again. This removes some of the

grease, and gives a fresh appearance to the deposit. Several points are to be noted in this connection so as to ensure a good result. First, the peripheral speed of rotation of the spindle and the diameter of the mop. The lower the speed, the longer an article will take to finish, and thus lower the output will be. On the other hand, if the speed be too great, too much of the deposit will be removed, and a sufficiently thick deposit may become too thin. Secondly, a compo containing an abrasive should not be used to finish soft metals. The result would be both poor finish and waste. Thirdly, it is important that the melting point of stearin used in the compo should not be too high, if it is, the mop will become clogged.

burnt dark and often powdery, consisting of both metal and oxide. If the current is lowered, good deposit formed is liable to strip from the defective areas.

(d) Same as (b)

(e) After a deposit has attained a thickness of more than some 2000th of an inch, it is liable to peel. The thickness attained is variable; a hard and brittle deposit will peel sooner than one that is soft and malleable. It is commonly said that peeling as the result of thickness is caused by the contractive force that exists within deposited metal.

Another case of defective deposition is where peeling occurs as in the case of deposition of aluminium.

Another cause of formation of little or no deposit is the presence in the bath of an excess of some substance that is capable of dissolving the deposited metal, e.g., the presence of excess of cyanide in the depositing bath. Another cause is the presence of an excess of some component that yields cations which are discharged in preference to those of the metal, e.g., excess of sulphuric acid in the depositing

bath. The remedy in either case is to neutralise some of the excess of free cyanide or acid by adding a suitable metal-containing salt such as a cyanide of a metal and carbonate of metal, respectively. Still a third cause is an inefficiency of metal in the solution. If there is little or no metal present, little or none can be deposited; metal salt must be added

DEFECTIVE DEPOSITS

One of the most frequent causes of defective deposit is the appearance of some defect on or in the deposit such as, cracking or splitting caused by expansion or contractions in the deposited metal; laminations due often to interruption of the current or to other changes in the conditions of deposition; holes, which may be due to gas or solid substance having been included in the deposit during its formation

Abnormal electrical resistance may arise in several ways. A common cause is the fouling of the anodes by insoluble deposits. In cyanide solutions if there is an insufficiency of free cyanide to dissolve the salts formed at the

anode, these salts separate on the anodes' surface and form non-conducting layers upon them. The formation of gas bubbles and their adhesion to the cathode's surface sometimes cause quite a considerable rise in resistance.

Bad electrical connection will, of course, operate to raise the resistance of a bath, as also does poverty in conducting salts.

STAINING.

Staining is a post-deposition trouble. If the articles are not quickly dried after removal from the plating solution, they are liable to become marked with stains, especially if the articles have poor deposits upon them. The preventive is quick and efficient drying.

SPOTTING OUT

It has already been stated that all metals are more or less porous, and that the plating solution entering into them cannot be easily got rid of during the subsequent drying out process. It will gradually ooze out at some future time. Now if the liquid is corrosive it dissolves some of the deposit round the mouth

of the pores thereby disfiguring the plated goods.

To prevent the formation of this defect the articles should be dipped after plating in boiling water so as to expand the pores of the metal. But sometimes the articles are immersed in hot solution of boric or oxalic acid that will destroy the corroding liquid or convert it into a non-corroding substance

CHAPTER IX.

COPPER-PLATING.

COPPER plating is treated first, as it is a preliminary to much of the nickel, silver and even gold plating, because these metals deposit more easily and firmly on copper than on any other metals. Rough goods when highly polished and coated with copper will turn out a good job in the nickel or silver plating tank. If repairs are necessary, they should be made smoothly by soldering them over and polishing them as coppered surface.

There are two types of bath solution used in copper plating. Each has a definite advantage over the other according to the nature of the work they have to perform. Where a comparatively thin deposit is required for protective or decorative purposes, alkaline bath is the most suitable; but where simply a cover coat or thick deposit is required, acid bath may be employed with advantage. Let us deal with the two processes one after another.

ACID SOLUTION.

This solution used by electro-platers for copper plating is very simple consisting of the following:—

Copper sulphate	2 lbs.
Sulphuric acid	6 oz.
Distilled water	1 gallon.

The presence of acid prevents the formation of basic salts within the bath and adds to the throwing power by the reduction of the number of free copper ions in the solution

ADDITION AGENTS

With a view to improve the character of the deposit some addition agent is indispensable. Those which are known to work satisfactorily are:—

Alum, glue, gelatine, phenol, etc.

ANODES

In copper plating pure copper anodes are generally used. But being crystalline in structure the metal between the crystals is readily dissolved, leaving the crystals free to fall from the plate. This red powder may float in the solution, become attached to the

cathode and cause roughness. For this reason it has been proposed to deposit copper on perforated lead plates and use these as anodes.

ARTICLES SUITABLE FOR COPPERING.

In copper plating it is impossible for many metals to be plated with this solution, which is acid and easily decomposed. Only brass and other copper alloys will stand the action of the solution. All base metals may therefore be plated in alkaline bath described latter on

CURRENT DENSITY

In the solution mentioned above and used without any movement a current density of 25 to 30 amperes per sq. ft. can safely be used. When rapid deposition is required, the current density can be considerably increased by imparting motion to the solution. With low acid the copper is soft and easily buffed, and this is required of the copper which forms the undercoat for nickel. Harder deposits may be obtained for solution containing high acid content.

DETACHABLE DEPOSITS

When acid bath is used the deposits obtained on copper can be easily detachable by

treating the copper or brass surface with a sulphide. In order to ensure good detachment the treated surface may then be covered with a thin wash of a solution of wax in alcohol. As the alcohol evaporates the layer of wax is insufficient to prevent deposition but permits of detachment. This process is largely employed in the manufacture of electro-deposit sheets.

TYPES OF VATS.

Copper plating vats are generally composed of wood with linings of 6 lbs lead sheet. Occasionally, for large tanks, slate is substituted.

ACID COPPER TROUBLES.

The troubles in this kind of bath are few in number and easy to eliminate. Dark powdery deposits are produced by using excessive current. Anodes will usually work dark, the black residue being an oxide of copper which falls to the bottom of the tank. If the anode works bright this may be regarded as some sign of too great acidity. If the throwing power is found to be very low, it may be improved by the addition of acid. The

separation of crystals indicates the need for more water.

COPPERING IN ALKALINE BATH

In preparing alkaline coppering solutions, for depositing a preliminary coating of copper upon iron, and for other purposes of electro-coppering any of the following formulas may be adopted

I.

Dissolve 4 ounces of copper sulphate in a pint of hot water. When cold, add gradually liquid ammonia of sp. gr. 880, stirring with a glass rod after each addition, until the precipitate which at first forms is re-dissolved, dilute the solution by adding 1 pint of cold water. Now prepare a solution of cyanide of potassium by dissolving about one-half pound of the salt in 2 pints of water, and add this gradually to the copper solution, with stirring until the blue colour entirely disappears. Finally add the remainder of the cyanide solution, and set aside the mixture for a few hours, when the clear liquor may be decanted into the bath and is then ready for use. The

solution may be used with a strong current, but it is advantageous to work it at about 130°F.

II.

Dissolve in a suitable pot 8 oz. of potassium cyanide in 1 gallon of water and add 4 oz. of dry carbonate of copper. This solution should be made up cold. If hot water is used it will change the properties of the copper carbonate. A portion of the powder will remain undissolved, and may lead to the belief that the chemicals are impure.

BRIGHTENERS

, In order to improve the quality of the deposit a number of materials are added to the copper bath. These are known as brighteners. They include small amounts of arsenious oxide dissolved in potassium cyanide. Other compounds are sodium thiosulphate, etc.

OPERATING CONDITIONS

With the solutions given above, a potential difference of 2 to 3 volts should suffice when the solution used is warm, a cold solution requiring a somewhat higher potential difference. Again in copper plating

the current density is of no great importance, the quality of the deposit being gauged by its appearance. The usual procedure is that of producing a perfect though light deposit on such metals as iron and steel, Britannia metal, zinc, etc., a thicker deposit of copper being then produced in the acid bath.

TROUBLES.

A number of common troubles in working the alkaline bath are easily rectified. The most common is that due to the lack of free cyanide. This may be ascertained from the colour of the solution which turns green. To remove this defect fresh cyanide solution should be added to the bath. The addition of cyanide first decolourises the solution and then allows the anodes to work clean. Again when the cyanide present in the solution is in excess, the amount of metal deposited is greatly reduced and at the same time the colour of deposit becomes dark along with blistery deposits. This excessiveness of cyanide may be removed by adding an appreciable amount of carbonate of copper.

CHAPTER X

GOLD-PLATING.

GOLD-PLATING or gilding is the most important branch of electroplating industry Cheap articles of jewellery are generally gilded to attract the fancy of customers Gilding is usually carried out in three different ways:

- 1 Gilding by simple Immersion or Dipping
2. Gilding by the employment of electric current or Electro-gilding.
- 3 Mercury gilding.

Strictly speaking, the first and the last do not come under the category of electro-plating It is important that these systems of gilding should be known to the electro-gilders for special purposes Hence these two processes are included in this book for the advantage of the platers

In gilding gold chloride is the main component It is available in chemist's shop but to

ensure its purity it is better to prepare by the platers for their own requirement. For this reason we begin with the preparation of gold chloride.

PREPARATION OF GOLD CHLORIDE

Since for all gilding purposes by the wet way, gold requires to be brought to the state of solution, it will be of vital importance at the very outset to explain the process of preparing the compound of gold commonly known as the chloride of gold. The most convenient way of dissolving the precious metal is to carefully place the required quantity in a glass bottle and to pour upon it a calculated amount of aqua regia—a mixture consisting of 2 parts of hydrochloric acid and 1 part of nitric acid by measure. To dissolve 1 ounce of gold (troy weight) about 4 ounces of aqua regia will be required, but this will vary with the strength of the commercial acids. As soon as the mixed acids have been poured upon the gold, chemical action commences with the brisk evolution of brown fumes. This action may be accelerated by placing the flask upon a sand-bath moderately heated. It is always

advisable, when dissolving this or other metal, in order to avoid the excess of acid, to employ less of the solvent than the maximum quantity in the first instance, and, when the chemical action has ceased, to pour off the dissolved metal and then add a fresh portion of the solvent to the undissolved metal, and so on until the whole is dissolved without any appreciable excess of acid, after which the various solutions are to be mixed together

The solution thus obtained is carefully poured into a porcelain evaporating dish placed on a sand-bath and gently heated to drive out the excess of acid, when the solution will assume a reddish colour. The red mass is next dissolved in distilled water forming a clear bright solution of chloride of gold

GILDING BY SIMPLE IMMERSION.

This process is successfully used in gilding a certain kind of cheap jewellery by simply dipping. The gilding solution can be prepared as follows: A strong solution of gold chloride is first prepared, to which acid carbonate of potash is added in the proportion of 1 part of gold chloride to 31 parts of the acid carbonate,

to this mixture is added 30 parts more of the latter salt previously dissolved in 200 parts of water. The mixture is then boiled for two hours, during which period the solution, at first yellow, assumes a green colour, when it is complete. To apply the above solution the metal articles of brass or copper, are first well cleaned and then immersed in the hot solution for about half a minute. Articles of German-silver or real silver can be gilt by placing the articles in this solution in contact with either a copper or zinc wire.

GILDING SOLUTION FOR STEEL

This gilding solution is usually prepared by agitating a watery solution of gold chloride with ether whereby the mixture separates into two portions on keeping; the upper stratum, which is of a yellow colour, is an ethereal solution of chloride of gold, while the lower stratum is merely water. Steel articles dipped in the ethereal solution become instantly covered with gold, and this method of gilding steel is very much useful for delicate surgical instruments, as also for the ornamentation of other articles of steel. After being applied,

the ether speedily evaporates, leaving a film of gold upon the object. If the ethereal solution be applied with a camel-hair brush or quill pen, designs in gold may be traced upon plain steel surfaces. Moreover, if certain portions of a steel object be protected by wax or varnish, leaving the bare metal in the form of a design, the ethereal solution may then be applied to the exposed surfaces, which will appear in gold when the wax or varnish is removed.

GILDING SOLUTION FOR SILVER

Dissolve equal parts by weight of sal-ammoniac and corrosive sublimate in nitric acid, now add some grains of gold to the mixture and evaporate the liquid to half its bulk; apply it hot to the surface of the silver articles.

GILDING SOLUTION FOR COPPER AND BRASS

Take fine gold $6\frac{1}{4}$ dwts and convert it into chloride, as before; then dissolve it in 1 quart of distilled water and add bicarbonate of potash 1 pound. Boil the mixture for two hours. Immerse the objects to be gilt in the warm solution for a few seconds up to one minute according to the activity of the bath.

GILDING SOLUTION FOR BRONZE, ETC.

The bath for gilding by simple immersion is composed of:—

Caustic potash	180	parts
Carbonate of potash	20	„
Cyanide of potassium	9	„
Distilled water	1000	„

A little more than $1\frac{1}{2}$ part of chloride of gold is dissolved in water; then the other substances are to be added and the whole boiled together. The strength of the solution is maintained constant by the addition of gold chloride from time to time, and also, after being worked four or five times, by addition of other salts in the proportions indicated. This bath is very suitable for gilding small articles of cheap jewellery.

ELECTRO-DEPOSITION OF GOLD

In gilding by simple immersion, it is obvious that only a limited amount of gold can be deposited upon the article, which we shall deal just now. But by the help of this process gold may be deposited to any required thickness and also upon many articles which would not be gilt properly by simple immersion. This method is known as Electro-

gilding, which is performed either with hot or cold solutions; but for most practical purposes hot solutions are preferred. When gold is deposited in cold solutions, the colour of the deposited metal is generally yellow, and not of the rich orange-yellow tint which is the natural characteristic of fine gold; the deposit, moreover, is more crystalline, and consequently more porous in cold than hot solutions, and is therefore not so good a protective coating to the underlying metal. The gold deposited from warm solutions is not only of a superior colour and of closer texture but also obtained with much greater rapidity. That is to say, an article may be gilded of the finest gold colour with an appreciably small quantity of precious metal. This is due to the superior conductivity of hot gilding solutions. This enables any one to gild various metallic surfaces, such as tin, lead, Britannia metal, and even steel, which could not be accomplished satisfactorily with cold solution.

PREPARATION OF 24-CARAT GILDING SOLUTIONS

Of all solutions of gold ordinarily employed in electro-gilding by the direct

current, the double cyanide of gold and potassium is indoubtedly the best, and has far more extensive application than any other. In order to make one quart of this solution, convert $1\frac{1}{2}$ penny-weights of fine gold into chloride as before, then dissolve the mass in about half a pint of distilled water and strain through a filter paper. Next dissolve about half an ounce of potassium cyanide in four ounces of cold water. Gradually add this solution to the chloride of gold stirring with a glass rod. On the first addition of the cyanide the yellow colour of the chloride solution will disappear, and on further additions a brownish precipitate will be formed. When no further precipitation takes place, the addition of cyanide is stopped.

To determine the right point at which to stop, the precipitate should now and then be allowed to fall, so that the clear supernatant liquor may be tested with a drop of the cyanide solution. If by accident the cyanide solution is added in excess, a little more chloride of gold must be added to neutralise it. The precipitate must be allowed to settle, when

the supernatant liquor is to be poured off, and the precipitate washed several times with distilled water. Lastly, a little distilled water is to be added to the precipitate, and a sufficient quantity of cyanide solution must be added, and the solution then made up to one quart with distilled water. Before adding the final quantity of water it is a good plan to pour the concentrated solution into an evaporating dish, and to evaporate it to dryness over a sand-bath, after which the resulting mass is to be dissolved in one quart of hot distilled water. The solution should be filtered before using, and must be worked at a temperature not below 120°F nor above 130°F.

II

Prepare the gold chloride with $1\frac{1}{2}$ pennyweights of gold as before, and dissolve in half a pint of distilled water; precipitate the gold with ammonia, being careful not to be added in excess. The precipitate is to be washed as before, but must not be allowed to become dry, since it will explode with the slightest friction when it is in that state. A strong solution of cyanide is next added until

the precipitate is dissolved. The concentrated solution is now filtered, and finally distilled water is added to make one quart. About 20 pennyweights of fine gold should be used for the anode.

III.

Gold chloride	1	part.
Potassium ferrocyanide	10	parts
Water	100	„

Dissolve the solids in the water and filter. Now add 100 parts of a saturated solution of potassium ferrocyanide and dilute the mixture with twice its volume of water.

COLD ELECTRO-GILDING SOLUTIONS

The cold gilding bath is sometimes used for very large objects, as clocks, etc. to avoid the necessity of heating great volume of liquid. As in the case of hot solutions, the proportions of gold and cyanide may be modified considerably. For most practical purposes of cold gilding, the following formulas are recommended —

I.

Fine gold	10	parts
Potassium cyanide	20	„
Distilled water	1000	„

Convert the gold into chloride, as before; then dissolve it in about 200 parts of distilled water. Next dissolve the cyanide in the remaining water, and if necessary, filter. Mix the two solutions and boil for a short time. When the strength of the solution becomes weakened by use, it is augmented by adding a strong solution of cyanide of gold, prepared by adding a solution made from 1 part of solid chloride dissolved in a little water, and from 1 to $1\frac{1}{2}$ parts of pure cyanide of potassium, also dissolved in distilled water, the two solutions being then mixed together.

II.

Potassium ferrocyanide	20	parts
Carbonate of potash	30	„
Sal-ammoniac	3	„
Gold chloride	15	„
Distilled water	1000	„

All salts, excepting the chloride of gold, are to be added to the distilled water. The mixture is then boiled, and afterwards filtered. The chloride of gold is next to be dissolved in a little distilled water and added to the filtered liquid.

PREPARATION OF 14-CARAT GOLD PLATING SOLUTION

A good 14 carat gold plating solution is composed of water, 1 gallon; potassium cyanide, 10 ounces, gold chloride, 10 pennyweights, and a sufficient amount of carbonate of copper to give the desired shade. A 14-carat gold anode should be employed composed of 235 parts of fine gold formed alloy with 80 parts of copper, 83 parts of zinc, and 6 parts of nickel.

PREPARATION OF THE WORK

In electro-gilding small articles such as brooches, lockets, watch chains, etc. it is generally sufficient to well scratch-brush and rinse them, after which they are at once put into the bath. A preparatory dip in a hot potash bath may be resorted to. After scratch-brushing, a short length of copper 'slinging' wire is attached to the articles, and the free end is connected to the negative electrode of the battery by simply coiling it around the stouter wire several times; the ends of both wire however, should previously be cleaned by means of a piece of emery cloth. When the articles are first dipped into the solution, they should be

gently moved about, so that the deposit may be regular. For detailed process of cleaning articles, readers may refer to the special chapter already dealt with

MANIPULATIONS OF ELECTRO-GILDING

In small gilding operations, the apparatus and arrangements are of an exceedingly simple character, and need not involve more than a trifling outlay. A Daniell cell or a small battery will answer well. The gilding bath may consist of one quart of solution, prepared from any of the formulas given, a square piece of gold plate, about 2 by 2 inches, weighing about five pennyweights, or even less, will serve for the anode; and the articles to be gilded are connected to cathode. An enamelled iron saucepan may be used to contain the solution. Since gilding baths require to be used hot (about 130°F), there must have some heating arrangement

With this arrangement, it is quite possible to gild small articles, such as brooches, locket, etc. and provided the gold anode be replaced, as it becomes worn away in use, and the solution kept up to its normal height by the addi-

tions of distilled water to make up for loss by evaporation. The same bath will be capable of gilding a good amount of small work.

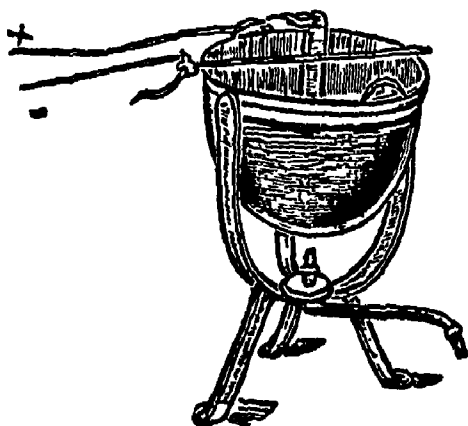


Fig 10 Gilding outfit

Gilding on a somewhat larger scale may also be pursued without any very great outlay, and yet enable the gilder to do a considerable amount of work in course of a day. The battery for supplying electrical energy should be a one-gallon Bunsen or 18-inch Daniell cell; for the anode, two or more ounces of fine gold rolled to about 6 by 3 inches, to which a stout piece of platinum wire and not copper wire should be attached by means of gold solder for keeping the anode wholly immersed in the solution when a large surface is required. A small binding screw may be employed to connect the platinum wire with the positive electrode of

the battery A simple method of heating the gilding solution is by placing the bath over a tripod stand beneath which is a perforated gas burner For brightening small articles the hand scratch-brush may be used

COLOUR OF GILDED ARTICLES

The colour of gilded articles may be varied from a pale lemon colour to a dark orange-red at the will of the operator, thus, when the solution employed is in cold state, a pale lemon-coloured deposit will be obtained Moreover, if the bath used is warm, a small surface of the anode is exposed in the solution, and the article is kept in brisk motion, the deposit will also be of a pale colour If, on the other hand, there be a large excess of cyanide in the bath, a considerable surface of the anode is immersed and a strong current is allowed to pass, the gilding will be of a dark colour In order to obtain uniform results of any desired shade, care must be taken to keep the temperature of the bath uniform, the anode surface immersed in solution is the same for each batch, the battery current as uniform as possible, and the volume

of the solution kept constant by adding distilled water from time to time.

FROSTED GILDING.

In this process the deposit instead of being more or less bright when removed from the gilding-bath may present frosted appearance, which is not only beautiful but is absolutely necessary for certain classes of work. To obtain a deposit of somewhat dead lustre, copper and brass articles are dipped for a moment in a mixture of equal parts of sulphuric acid and nitric acid, to which is added a small quantity of common salt. The articles are slung on a stout wire, coiled into a loop, and dipped into the nitro-sulphuric acid "dip" for an instant, and immediately rinsed in clean water, kept ready in a vessel near the dipping acid. If not sufficiently acted upon, the articles must be again immersed in the dip for a moment and rinsed in water for several times and immediately put into the gilding bath, a little delay in transferring causes the articles to be oxidised. If mercury dip is employed, the work must be dipped in the quickening bath immediately after they have been rinsed from the acid dip.

DEFECTIVE GILDING

When the gold becomes partially dissolved off portions of an article while in the gilding bath, it indicates the presence of cyanide in excess in solution. The same defect may be caused by using too weak current, insufficient amount of gold in the bath, small anode, or by keeping the articles too briskly in motion in a bath containing a large excess of cyanide. Moreover, when the current is too strong, the work is destroyed because the gold is deposited in a loose, powdery form, reddish brown in colour. Hence to obtain a perfectly gilded article the above mentioned sources should be eliminated with great dexterity.

GILDING SILK AND COTTON FABRICS

There are several methods by which textile fabrics may be either gilt or silvered. One method is to stretch the fabric tightly upon a frame, after which it is immersed in a solution of acetate of silver, to which ammonia is added, until the precipitate at first formed becomes dissolved, and a clear solution obtained. After immersion in this solution for an hour or two, the thread or fabric is first dried, and then

submitted to the action of hydrogen gas, by which the silver becomes reduced and the surface metallised. In this condition it is a conductor of electricity, and may be either gilt or silvered in any ordinary cyanide solution. By another method, the piece of white silk is dipped in an aqueous solution of chloride of gold, it is then exposed to the fumes of sulphur dioxide gas, produced by burning sulphur in a closed box, when in a very short time the entire piece will be coated with the reduced metal.

MERCURY GILDING.

Mercury gilding is perhaps the oldest method and is still in practice for gilding uneven articles. The operation can be done very cheaply by the process of amalgamation. Hence an amalgam is indispensable in this gilding. As this article is not always available it is better to prepare this stuff by the plater himself.

PREPARATION OF THE AMALGAM

To prepare the amalgam of gold for the purpose of mercury gilding, a weighed quan-

tity of fine gold is first put into a crucible and heated to dull redness. The requisite proportion of mercury—8 parts to 1 part of gold—is now added, and the mixture stirred with an iron rod, the heat being kept up until the gold is entirely dissolved by the mercury. The amalgam is now poured into a small dish about three parts filled with water, in which it is worked about with the fingers under the water, to squeeze out as much of the excess of mercury as possible. The amalgam is further squeezed in a chamois leather bag by which a further quantity of mercury is removed; the amalgam which remains after this final treatment consists of about 33 parts of mercury and 67 parts of gold in 100 parts.

MERCURY SOLUTION.

To apply the amalgam, a solution of nitrate of mercury is employed, which is prepared by dissolving, in a glass vessel, 100 parts of mercury in 100 parts of nitric acid of sp gr 1.33, gentle heat being applied to assist the chemical action. The poisonous red fumes which are given off during the decomposition must be allowed to escape into the chimney.

When the mercury is all dissolved, the solution is to be diluted with about 25 times its weight of distilled water, and bottled for use

PROCESS OF APPLICATION.

In applying the amalgam the pasty mass is spread with the blade of a knife, upon a flat stone and the article, after being well cleaned and scratch-brushed, is treated in the following way. The operator takes a small scratch brush, which is first dipped in the mercury nitrate solution, and then draws it over the amalgam, by which it takes up a small quantity of the composition, he then passes the brush carefully over the surface to be gilt, repeatedly dipping the brush in the mercurial solution and drawing it over the amalgam until the entire surface is uniformly and sufficiently coated. The article is afterwards well rinsed and dried. These are next burnt in a charcoal fire, covered with a hood to protect the operator from inhalation of mercury vapour. The articles are turned with a long pincers until the mercury vaporises. They are then taken out of the fire, washed and coloured in the usual way

CHAPTER X.

ELECTRO-DEPOSITION OF SILVER.

PREPARATION OF SILVER NITRATE.

SINCE silver-plating solutions are generally prepared from the nitrate of silver, it will be necessary to consider at the very outset its preparation. To prepare it the required quantity of metallic silver is carefully put into a capacious glass vessel or stone or enamelled ware, otherwise a portion of the metal may be lost by the spitting of the solution when the chemical action is at its height. In dissolving silver take—

Pure silver	4 ounces
Pure nitric acid	7 „
Distilled water	3 „

Put the silver carefully into the vessel, then add the water, and lastly the acid. In a few seconds vigorous chemical action sets in with the evolution of brown fumes. When the action begins to quiet down a little, the flask must be heated either by placing it on sand-bath or otherwise. It is allowed to re-

main in this condition so as to finish the chemical action. It may be well to mention that, in dissolving silver, it is advisable in the first instance to use rather less of the acid than is necessary to dissolve the whole of the silver, and to treat the undissolved portion separately, by which means excess of acid is avoided. The solution of silver nitrate is now evaporated by placing the vessel over sandbath until a film forms on the surface of the liquor. At this stage it is set aside to cool. After a few hours, crystals of silver nitrate collect at the bottom of the vessel. The remaining liquid is then again evaporated as before. In this way the whole of the silver taken is converted into nitrate, which is next dissolved to produce electro-plating solution.

SILVER SOLUTION FOR ELECTROPLATING.

The solutions of silver used for electroplating are commonly known as cyanide solutions. The foremost of these solutions is the double cyanide of silver and potassium, which is prepared as follows:

Convert an ounce of silver into nitrate, as before, and then dissolve it in about 4 pints

of distilled water in a suitable vessel. Next gradually pour into it a strong solution of potassium cyanide (about $\frac{1}{2}$ a pound, dissolved in 2 pints of water) to precipitate the whole of the silver as cyanide. Each time after adding the cyanide solution, the mixture must be well stirred with a glass rod. When it is found that the addition of cyanide produces but little effect, it must be added very cautiously, since an excess will redissolve the precipitate and cause waste in the subsequent process of washing this deposit.

Here the precipitate is allowed to settle. The supernatant liquor is then decanted off without disturbing the solid matter. Next pour a large quantity of fresh water with brisk stirring, then allow the precipitate to settle and finally pour off the liquor as before. This addition of water and its decantation should be repeated three or four times so that the silver cyanide would be free from any impurities.

Now to convert the cyanide of silver into the double cyanide of silver and potassium, add strong solution of potassium cyanide in moderate portions at a time with constant stirr-

ing as before, until the precipitate appears nearly all dissolved, at which stage the additions of cyanide solution must be made with more caution. In this case it is a good plan to allow the vessel to stand for a short time, then to pour off the clear liquid, which is now a solution of double cyanide of silver and potassium, and to treat the remainder of the precipitate with fresh cyanide solution. In this way an excess of the solvent can be avoided. When all the precipitated silver is redissolved, add about $\frac{1}{4}$ th more cyanide solution than that originally used, and pass the solution through a filter into the plating bath. The solution is finally to be made up to the full quantity by adding the necessary proportion of water, when its preparation is complete, it will be better to allow it to rest for twenty-four hours before using it for electro-plating.

II

Take an ounce of silver and convert it into nitrate as before. Then dissolve the crystals in from three to four times of distilled water. Gradually add a solution of carbonate of potash, consisting of about 6 or 8 ounces of

the compound to a pint of water, until no further precipitation takes place. After allowing the precipitate to settle for some time, pour off the clear liquor and wash the precipitate with water several times to free it from any suspended impurities. Then add a strong solution of potassium cyanide so as to dissolve the precipitate. Lastly, put into it a little excess of cyanide to convert it into double cyanide solution. The solution should now be filtered and water added to make up one gallon.

III.

For plating ordinary German silver articles, a liquid composed of sulphate of silver dissolved in a solution of carbonate of ammonia is preferable. It can be prepared by adding a solution of sodium sulphate (Glauber's salt) to a solution of silver nitrate. But for plating better qualities of German silver dissolve cyanide of silver in a solution of carbonate of ammonia. The proportions are as follows:—

ANODES.

Anodes for silver bath should be of fine silver and not sterling, which is not pure.

They should be annealed to render them more easily attacked and so maintain the silver content. They must not be suspended by any attackable metal which will be exposed to the solution.

On working, they become dull owing to the temporary formation of the insoluble silver cyanide, which, however, dissolves in the free cyanide. Occasionally a slight black deposit occurs on them, due, possibly, to the formation of an oxide.

VATS

There are several materials available for the construction of silver-plating vats. Glass or porcelain makes a clean container for the solution on the small scale. Enamelled iron on the larger scale is possible but, more usually, lead-lined wood tanks are serviceable.

CATHODE CONNECTIONS

The design of the cathode bars and connections will depend mainly upon the nature of the work to be handled. Generally they are arranged upon frames to which may be imparted a slight reciprocating motion so that the

the work can be kept slowly moving. This slow motion of articles during the time of plating gives an improved deposit upon the articles in addition to keeping the solution gently stirred

QUICKING.

For obtaining a good deposit upon brass, copper, etc this treatment is indispensable. Quicking solution suitable for silver plating is composed of the following—

Mercuric oxide	1 oz.
Sodium cyanide	3 oz
Distilled water	1 gallon

Dissolve the sodium cyanide in a small quantity of water and the mercuric oxide then readily dissolves in this solution, after which the bulk of the solution is made up with the rest of water.

In this solution the articles are dipped momentarily, receiving a bright film of mercury, which promotes, adhesion of the silver deposit

BRIGHT PLATING

In order to change the dull appearance of the plated articles to bright ones a few grains of

carbon disulphide may be added to the bath. To perform this operation a few ounces of carbon disulphide is shaken with a gallon of the solution, when a portion passes either into solution or intimate suspension. After allowing to settle, the clear liquid is added to the main bath in small dose of one fluid ounce for every 10 gallons.

DOCTORING.

In silver plating it will be found occasionally that portions of plated articles are unsatisfactorily plated. To remove these defects a small piece of silver covered rag is made the anode and the work to be "doctored" the cathode. The anode is dipped in the plating solution and applied to the defective part which has been suitably cleaned. The solution in the "doctor" can be replenished from time to time, and the defective area thus corrected.

RATE OF DEPOSITION.

The rate of deposition of silver depends largely upon the metal content of the solution. When this is high the rate of deposition can be

increased. The usual practice is to pass slow current at the rate of 3 amperes per sq. ft. when the silver content is as low as 1 ounce per gallon, while with a stronger solution a rate of 6 amperes per sq ft may easily be maintained.

TROUBLES.

There are serious difficulties attaching to the working of the silver solution. Lack of free cyanide is the most likely. Insoluble single cyanide of silver then collects on the anodes and offers undue resistance, and hinders the maintenance of the correct current density. This error can be easily rectified by adding fresh cyanide solution. Now to keep the anodes clean it is usual to keep the solution in agitation. Other troubles may be removed by keeping the solution free from suspended matter

Sulphate of silver	78 parts
Carbonate of ammonia (dis- solved in distilled water)	35 parts.
<i>or</i>	
Cyanide of silver	67 parts.
Carbonate of ammonia	35 ..

Boil the silver salt with the solution of the carbonate of ammonia, until it is dissolved.

BRIGHT-PLATING

The silver deposited from ordinary cyanide solutions is generally dull white or pearly white, according to the condition and nature of the silver solution, and the strength of the current. Hence it is necessary to brighten the work by scratch-brushing before it is subjected to the operations of burnishing or polishing. Addition to the plating bath of a small quantity of bi-sulphide of carbon, gives bright, not dull, deposits of silver.

To prepare the solution for bright-plating, the following method is adopted: Put 2 pints of ordinary silver plating solution into a large stoppered bottle; now add 1 pint of strong solution of cyanide of potassium and shake well, 4 ounces of bisulphide of carbon are then to be added, as also 2 to 3 ounces of liquid ammonia, and the bottle again well shaken, which operation must be repeated every two or three hours. The solution is then kept aside for twenty-four hours when it will be ready for use. About 2 ounces of the clear liquid may be added to every 20 gallons of ordinary plating solution, and well mixed by stirring.

REPLATING STEEL ARTICLES

The following simple and practical method of replating old steel articles such as knives, scissors, forks, tongs, etc is reproduced from Electroplating by *Reetz*:—

The articles are first cleaned in a hot solution of soda or potash. The silver is then stripped in a solution of 1 lb of potassium cyanide and 1 lb of caustic soda in 1 gallon of water, in a plating tank. The articles are next hung in a bunch as an anode by means of an iron wire, and a piece of cleaned sheet steel is used for the cathode, this operation being the exact reverse of plating. A strong current upto 6 volts may be used, as the cyanide does not attack the steel surface. The silver is deposited on the sheet steel in the form of a spongy coating, some of which falls to the bottom of the tank. Shake the knives occasionally to facilitate throwing off the silver. If it is found that there is a nickel plate under the silver, which will resist the stripping process, the grinding wheel may be resorted to for its removal. The surfaces of the articles are next polished in the usual

manner by holding them over the emery wheel and finished with felt and flour emery

The articles are now dropped in a solution of 8 oz of sal-soda in 1 gallon of water, to prevent them from rusting. After dipping for a few minutes in the hot lye, the articles are dipped in cold water and scoured with pumice and a stiff bristle brush. Use dilute sal-soda with the pumice to keep the steel from rusting. This is much better and safer than the poisonous cyanide. All stains and rust spot must be carefully scoured out, emery powder being used if necessary. After thorough scouring, rinse in cold water, and put through the potash solution to remove grease. The articles should not be left out in the air, or they will rust, but if the plating tank is not ready they should be placed in the sal-soda solution. Do not touch with the hands. After plunging them in the lye, the steel articles are rinsed in cold water and passed quickly through the dip composed of 1 pint of hydrochloric acid to 1 gallon of water. The goods should now be free from all grease and oxidation.

The goods being cleaned are placed in the tank with silver anodes on both sides to secure an even deposit. The anode surface should exceed that of the goods. Use a weak current, not over 1 volt, and move the articles in the bath often while the plating is going on. To secure what is called a "12" pennyweights of silver to the dozen knives, they should remain in the bath for $1\frac{1}{2}$ to 2 hours. When the operation has been completed, the articles are taken out, scratch-brushed and buffed with a soft rag wheel and silver rouge, care being taken not to use too much rouge.

SILVER PLATING BY SIMPLE IMMERSION.

It is a fact that articles of brass and copper readily become coated with a film of silver, without the aid of the electric current, in tolerably strong solutions of the double cyanide of silver and potassium, but the deposit so obtained is not of such a degree of whiteness as to be of any practical use. Other solutions of silver are therefore employed when it is desired to give a slight coating of this metal to small brass or copper work which will present the necessary brilliant white colour. Silver may

also be deposited upon these surfaces by means of a paste of silver chloride, to which common salt or cream of tartar is added. The following processes* are those most generally adopted.—

“For small brass and copper articles, as buttons, hooks and eyes, etc., silvering by simple immersion is employed; and in order to produce the best possible effect, the solution bath should not only be prepared with care, but kept as free as possible from contamination by other substances. To prepare a bath for this purpose, a given quantity of fine grain silver is dissolved in nitric acid. The solution of nitrate of silver thus formed is added to a large quantity of water, a strong solution of common salt is then poured in, which precipitates chlorine of silver in the form of a dense white precipitate. When the whole of the silver is thrown down the precipitate is allowed to subside, after which the supernatant liquor is poured off, and the precipitate washed several times. The precipitate, which is very readily acted upon by sunlight, should be prepared in

* Reproduced from *Electro-plating and Electro-Refining* by Watt and Philip

a dull light, or by gas light, and, if not required for immediate use, it should be kept in deep coloured bottle and kept in a dark cupboard. The chloride of silver is to be mixed with at least an equal weight of cream of tartar, and only sufficient water is added to form a pasty mass of the consistency of cream. In this mixture the articles, having been previously cleaned are immersed, and stirred about until they are sufficiently white, when they are to be rinsed in hot water, and shaken up with saw dust.

Another chloride of silver paste, for whitening articles of brass or copper, may be prepared by taking chloride of silver and prepared chalk, of each one part, common salt $1\frac{1}{2}$ parts, and pearl ash 3 parts, made into a paste as before. A third mixture is prepared by taking chloride of silver 1 part, cream of tartar at least 80 parts, to which is sometimes added about 80 parts of common salt. The whole is dissolved in boiling water. In using this solution the articles are introduced by means of a perforated basket, which is briskly stirred about in the hot liquid until uniformly white.

SILVERING PASTE

In preparing paste, silver chloride and cream of tartar, with or without the addition of common salt, are made into a paste which should be well triturated in a mortar until it is impalpable to the touch. The paste is then spread, a little at a time, upon the brass surface and rubbed with a piece of soft cloth or cork. By thus working the silver paste over the metal, it soon becomes silvered, and a coating of sufficient thickness is obtained in a very short time. When the silvering is complete the article will be rinsed with pure water and dried in hot sawdust. Although a very slight film of silver is obtained in this way, its somewhat dull tone is specially applicable to such articles as clock-dials, scales of barometer and galvanometer, etc. and as it is not liable to tarnish due to atmospheric influences, it may be considered superior to all other methods of silvering.

CHAPTER XI

NICKEL PLATING.

NOW we come to nickel plating, which may be considered as one of the most important branches of the art of electro-deposition

PREPARATION OF NICKEL SALT.

Although many solutions have been proposed, that for all practical purposes in the electro-deposition of nickel, a solution of the double sulphate of nickel and ammonium, with or without the addition of common salt, will be found very suitable in producing uniform coating. In order to prepare it in pure state a quantity of oxide or carbonate of nickel is dissolved in dilute sulphuric acid (1 part acid to 2 parts water). The resulting solution is then neutralised with ammonia and crystallised. To each pound of the dry crystals add 1 pound of pure sulphate of ammonia, dissolve the mixed salts, evaporate the solution, and re-crystallise. Cube or grain nickel may also be taken for this purpose. It is first dissolved in

a mixture composed of 1 part of sulphuric acid and 2 parts of water, with the addition of a small quantity of nitric acid by the application of gentle heat. The solution is then to be evaporated and set aside to crystallise, and to convert the sulphate of nickel into double salt, sulphate of ammonia is to be added in the same proportion as before; the mixed salts must be dissolved, filtered and crystallised

PREPARATION OF THE BATH SOLUTION.

In making up a bath from the double sulphate prepared by either of the above methods, about 12 ounces of the dry crystals are to be taken for each gallon of the bath, and the crystals should be dissolved in sufficient quantity of hot water, the solution filtered, and the requisite quantity of cold water added to make up the full quantity of the solution in the proportions mentioned above.

Other useful formulas for the preparation of bath solution are:—

I.	
Double nickel salts	4 ounces
Single nickel salts	8 "
Distilled water	1 gallon
Procedure as above	、

II.

Single nickel salts	48 ounces.
Sodium chloride	$\frac{1}{2}$ ounce.
Sodium fluoride	$1\frac{1}{2}$ ounces.
Boric acid	4 „
Water	1 gallon.

Procedure as above.

ACIDITY OF NICKEL SOLUTIONS

This factor is now considered as one of considerable importance in nickel plating. This acidity depends on the variation of current density, temperature and the irregular working of the electrodes

As it is not always possible to control the working of these exactly, it is desirable to have it corrected by the use of buffering reagents, such as boric acid, etc.

NICKEL ELECTRO-TYPING SOLUTIONS

While dealing with nickel solutions for various purposes, it may not be out of place to make reference to these in use for the special purpose of electro-typing. Here the special requirements is that of the deposition of nickel over a graphited surface. This is not possible with a solution containing nickel sulphate only.

The addition of an ammonium salt at once produces satisfactory deposits

	I	II
Nickel sulphate	24 ounces	1·4 lbs.
Ammonium chloride	2 „	2½ ounces.
Distilled water	2 gallons	1 gallon

The recipe I is applicable to wax, while II is suitable for lead moulding

TYPES OF VATS.

Nickel-plating vats are generally made of wooden planks secured in their position by means of screw-bolts. The interior of them is well lined with pure lead sheets; otherwise they would be liable to be acted upon the nickel solution forming holes, through which the solution will eventually leak out. The joints of the leaden lining must not be united by means of solder but by autogenous welding. If solder were used for this purpose voltaic action would soon be set up between the lead and the tin of the solder by the action of the nickel solution, and in course of time a series of holes would be formed. When the lead lining is complete the vessel must be lined throughout with match boarding, kept in its

position by a rim of wood fastened round the upper edge of the tank.

ANODES.

It has already been stated above that the nickel salts to be used for bath should be perfectly pure, it is equally important that the nickel plates to be used as anodes should be of the best quality. These may be either of cast or rolled nickel. Of these two varieties, the rolled nickel of moderate thickness may be advantageously employed owing to the fact that they give off the metal steadily and never become soft or fall to pieces while in the bath, as cast anodes; they are light and thin but durable.

PREPARATION OF WORK FOR NICKEL-PLATING.

The work which generally comes to the nickel-plater may be classified into a few groups:

(A) *Brass, Copper, Bronze, Gun Metal, etc*

These metals may be either stamped or cast. The stamped articles subsequent to buffing are subjected to following operations.—

(1) Removing grease with either the electric cleaner, or potash, or soda cleaner, (2) rinsing in warm water, (3) the application of a bright dip, (4) rinsing, (5) brushing with lime or whiting, and ample rinsing prior to passing to the nickel bath. The cast articles on the other hand, are full of pores. These should be removed prior to plating. For this purpose preliminary grinding with felt bobs and successively fine grades of emery is effected to develop a surface for the polisher. The same result may alternatively be obtained by rumbling in a barrel with steel balls and soap or by sand blasting. The choice of method will depend upon the nature of the castings. Subsequently, the work may be treated as those of stampings except that, wherever rinsing is applied to remove any liquid, the operation must be thorough to avoid the subsequent risk of spotting out.

(B) *Iron & Steel*

Sheet metals are generally coated with film of oxide. In order to remove this, they are treated in pickle tanks (p 26) with acid pickles as already stated on page 35. Very

little scouring should suffice to complete the cleaning.

For iron casting the general rules applicable to brass castings must be followed. Grinding must be applied to remove pores and then treated with pickles. After this it is well to give a light scouring with lime to neutralise residual acid.

(C) *Tin, Zinc and Lead Alloys*

After preliminary polishing with lime and stearine, the work is cleaned with soda ash solution. They are then scoured with lime or whiting, and transferred to the cyanide copper bath.

BLACK NICKELING.

In producing black nickel deposit the following solution is recommended.—

Nickel ammonium sulphate	10	ounces
Zinc sulphate	1 $\frac{1}{4}$	„
Sodium thiocyanate	2 $\frac{1}{2}$	„
Water	1	gallon

This solution is worked cold at a low voltage of 0.5 to 0.7 volt giving not more than 1 ampere per sq. ft. An increase in current density diminishes the blackness of the deposit, which becomes greyer in colour.

NICKEL PLATING DEFECTS.

In nickel plating there arises many difficulties due to susceptible nature of the solution, which does not allow the solution to work properly. If the work appears to receive little or no deposit and is discoloured there is the greatest possibility that the current is too low, this being brought about by unexpectedly high resistances of poor contacts, thin connecting wires and the like. The remedy for this is obvious.

The work may appear to be well nickelled but the deposit is rough and dull. This is commonly the result of too high a current density, which is easily remedied by reducing the strength of the current by suitably handling the rheostat.

Sometimes the deposit may show evidence of peeling. This is most usually due to too high a current density at least on prominent parts of the work, probably while the more remote parts are being covered. The obvious remedy for this is to increase the inter-electrode distance, making less difference between these two parts of the work.

Another common fault is the tendency to the production of black streaks on the deposit due to the presence of zinc in the solution. To eliminate this, high current density may be passed for a time.

Spotting out also occurs in nickel deposits due to imperfect methods of cleaning. To remedy these defects the articles should be treated in the manner described under Preparation of Work (page 119).

NICKELING BICYCLES, ETC

These articles may be nickeled in the ordinary bath with the exception of the rim of the wheel, and all parts must be polished and treated in the same way as other steel work. A convenient method of suspending bicycle spokes in the bath is done in the following manner. The copper slinging wire is simply coiled into a series of equidistant loops, through which the spokes pass freely, and when a sufficient number has been wired in this way the two ends of the slinging wire are pulled with both hands, by which the loops become tightened and the spokes held firmly. They are then lowered into the bath and sus-

pended from the negative rod. After a short immersion, each spoke is shifted a little, so as to allow the wire mark to be coated, and this operation is repeated several times during their immersion in the bath, so that the coating may be as regular as possible. With a dynamo-machine a sufficient coating will be obtained in about an hour and a half. In nickeling backbone and fork of a bicycle these pieces should be frequently shifted in the bath to ensure uniformity of deposit, for it must be borne in mind that from the peculiar curved form of the back bone the parts farthest from the anodes will receive the least deposit.

In cases where the bath is not large enough to take in the entire rim of a large bicycle wheel it is usual to nickel one-half at a time; when this has to be resorted to, great care must be taken to well clean the line where the deposited metal and the bare steel meet: otherwise, when depositing upon the second or third portion of the rim, the nickel will strip at the junction of the separate deposits. In each case, a portion of the nickelled part should be immersed in the bath with the uncoated

surface When finishing the rim, the operator should be careful with these functions of the separate deposits, otherwise he may readily cut through the nickel and expose the underlying metal

NICKELING OLD BICYCLES

In preparing an old bicycle for nickelling, the principal parts must first be taken asunder. All the parts, with the exception of the wheels are polished first It is not usual to remove the spokes, which in the case of a much-used machine would entail considerable risk, since much difficulty would occur not only in removing but in replacing them The wheels are, therefore, nickelled entire, but before doing so they must be polished in the best way possible by hand, since it would be impracticable to polish them at the lathe The spokes and other parts of the wheel are first well rubbed with emery-cloth of various degrees of fineness, and then hand-buffed with chamois-leather, first with sand, and afterwards with quick lime The wheels and other parts, when polished, are placed in the hot potash bath, where they are

allowed to remain for a considerable time to remove the large amount of grease which invariably hangs about this class of work. During this time the articles are rubbed with a brush. After being thus cleaned in the potash bath, the work is removed piece by piece and rinsed. After this, it is briskly scoured, and after again rinsing, is passed through the acid dip for an instant, again well rinsed, and put into the nickel tank. When all the parts of the machine are plated, they are polished with a lathe.

CHAPTER XII.

CHROMIUM PLATING.

NEXT to nickel plating there is no other metal found of such an immediate and wide range of application as chromium. Three properties of the deposit are mainly responsible for this, viz —

(i) Resistance to corrosion under most conditions, with the exception of the action of hydrochloric acid fumes

(ii) Its high polish, adding the note of decorative effect

(iii) Its extreme hardness, deposited chromium being one of the hardest metals yet produced

PREPARATION OF THE SOLUTION.

Chromium plating solutions, while containing the minimum of added constituents, are nevertheless of varying compositions and concentrations. The following as recommended by *Sargent* will serve many purposes:

embarking upon a stronger solution the plater must make preliminary experiments with a small bulk of solution

MAINTAINING THE STRENGTH OF SOLUTION.

A constant check in the composition of the solution must be kept. This is necessitated by the insoluble anodes used, and also the small variation of the proportion of chromic acid to sulphuric acid allowable. A simple type of test which can be undertaken in the workshop will not meet the purpose. It demands the skilled work of the chemist and necessitates the estimation of the free chromic acid, the combined chromic acid, iron and sulphuric acid.

Of these estimations that of the free chromic acid is the easiest and possibly the most important, as this material is almost solely responsible for the conductance of the solution. With the guidance of the accompanying table of densities of chromic acid solutions some idea of the requisite amount of chromic acid to be added from time to time will soon be gathered. The chemical testing and the electrical conductance determination will be advisable periodically.

STRENGTH OF CHROMIC ACID SOLUTIONS.

Beaume.	Sp gr.	Grms per litre	oz. per imp gallon.
10	1 07	100	16
11	1 08	114	18 2
14	1.10	143	22 9
16	1 12	171	27 4
18	1 14	200	32
20	1.16	229	36 6
21	1 17	243	38 9
22	1 18	257	41 1
23	1 19	272	43 4
24	1 20	288	46 1
25	1.21	301	48
26	1 22	316	50 6
27	1 23	330	52 8
28	1 24	345	55 2
29	1 25	360	57 9
30	1 26	375	60

When a solution is used at a temperature such as that recommended for chromium deposition, some portion of it will be lost by evaporation. To make up this loss small amount of water may be added from time to time.

SPECIAL ARRANGEMENTS OF THE VATS

For small scale experimental work, vats of glass or stoneware as recommended for gold plating will be found useful, but on the com-

mercial scale metallic tanks are the most suitable for their greater strength and reduced cost. Mild steel provides the best material.

In constructing a vessel, mild steel plates are welded together. In no way should they be riveted and bolted as these are quite unsatisfactory. These tanks are generally mounted on either a steel frame or a minimum of brick work and are supplied with steam pipes for heating purposes. In order to maintain the temperature constant some type of covering should be supplied. This may take the form of a simple brick work chamber built round the tank, or even an external asbestos lining. If the tank is to be heated, this may be done by the application of gas jets not directly impinging on the bottom of the tank, but on to plates welded to the bottom at the ends. This is to ensure that there is no local heating of the bottom of the tank as this too often leads to the attack of the chromic acid with thinning or even perforation of the plate.

Mounted on the steel tank, a substantial hard-wood frame provides a base upon which to mount the insulators carrying the anode and

cathode bars With the very heavy currents required for this type of plating these connections must be of a very substantial character Otherwise loss of power will occur with overheating of the connections. Good contacts between the anodes and bars must be assured, the suspensions being by flat strips rather than by even thick wires of circular sections with the cathode bars. Hooks should be riveted to the anodes All these contacts should be regularly inspected, overhauled and cleaned, as the unavoidable splashing of the chromic acid solution leads to the attack of all lead with the production of insulating lead chromate

MAINTENANCE OF TEMPERATURE

The temperature of operation of the solution is important Cold solutions give dull and hard deposits, requiring excessive labour in finishing. Warm solutions, on the other hand, give much brighter and softer deposits sometimes requiring very little finishing after deposition There are, therefore, limits of temperature between which the solution must be kept to produce the required deposit With

a rise of temperature there is a falling off in the amount of metal deposited per ampere hour.

From plater's point of view it may be said that a temperature of 45° to 50°C. (113° to 122°F) will be found to give good results. The watchful plater may find some variation from this range desirable for his particular purpose, especially with stronger solutions

ANODES USEFUL FOR CHROMIUM PLATING.

The decision as to the best type of anode has not been either a simple or a quick one. Anything in the nature of sheet chromium is out of question. Metallic chromium is not available in this form, nor is it likely to be. Its properties preclude this. Even in the lump form, in which it may be procured, there are two serious objections to it. First there is the cost. Metallic chromium is obtained with difficulty from chromic oxide. As an anode the chromium is at once converted to chromic acid. It would, therefore seem reasonable to supply the deposited metal by the addition of easily dealt with chromic acid, thus avoiding the high cost of extracting the chromium. Secondly, chromium as an anode is highly efficient. It

dissolves quantitatively. Assuming, therefore, a current efficiency of 12.5 per cent at the cathode, eight parts of the metal by weight would be dissolved at the anode for one part deposited at the cathode. The solution would soon become saturated and unworkable.

Lead anodes were therefore tried. These proved tolerably successful, except that they were proved to collect an insoluble and insulating film of lead chromate on the surface, this offering a high resistance, necessitating frequent cleaning, otherwise they would have proved acceptable. The difficulty was then got over by taking out the anodes when the solution was not in use. This, again was not ideal. The anode contacts must be substantial, and, therefore, once made, cannot readily be interfered with.

Finally, the difficulty has been got over by the use of chemically pure lead which has first been peroxidised by making it the anode in a solution of sulphuric acid. A lead cathode may be used. In a short time the lead anode is covered with a uniform brown and conducting layer of lead dioxide, which prevents attack

by the chromic acid, so that the anodes need not be removed from the solution except only occasionally.

Steel anodes have also been tried. They suffer the disadvantage of being attacked by the solution, the iron becoming soluble in the form of ferric dichromate. This locks up chromic acid in a combined form which is then not available for conducting purposes and moreover, may introduce undesirably large amounts of iron in the solution.

With regard to the size of the anodes, the old suggestion of having as large as possible again does not hold here. Large anode surface is productive of edge burning, while a more uniform distribution of current on the cathode results from a smaller anode surface. In addition, the smaller anode has the effect of encouraging deposition in the centre of the work, which is particularly desirable with large flat surfaces.

Several other suggestions for anode materials have also been made. Stainless steel is one. With this it might be arranged to dissolve chromium as fast as it is deposited,

but there would also be the undesirable solution of the iron. Lead containing about 6 per cent of antimony makes a good anode, and is in successful commercial use. This might be anticipated from the use of this alloy in the lead accumulator. Whatever lead chromate forms on its surface is readily removed by brushing, the layer of antimony oxide preventing its firm adhesion.

In order to keep down the anode surface the use of lead strip is resorted to. Such anodes can be conveniently placed to produce the required distribution of the current, where sheets are being dealt with this strip anodes may well have about two-thirds of the area of the cathode.

CURRENT DENSITY.

Chromium deposit is unique in the very high current densities usually employed to obtain commercial deposits. At first a current density of 92 amperes per sq ft was recommended, and while good deposits may be obtained with this or on even lower figure on flat work, experience has determined that for more irregular work with which the plater will

come into contact, a higher current density will be found desirable. The usual figure, therefore, is of the order of 100 to 200 amperes per sq. ft., dependent upon a number of conditions such as concentration of the solution and its temperature. For general work in the solution recommended, a current density of 100 to 150 amperes per sq. ft. will be found to suffice.

THROWING POWER.

This is an all important point in connection with chromium-plating. The ordinary types of solution do not throw well. With a low current density on irregular work the recesses may receive no appreciable deposit. The first requirement is an increase in current density and in computing this it must be remembered that exposed parts of the work not receiving deposit may nevertheless be receiving current, thus lowering the current density on the more important parts requiring plating.

TYPES OF DEPOSIT.

There are three well defined types of deposits produced in chromium plating, differing more markedly than with most electro-

deposited metals. These depend upon a number of conditions. Dealing first with current density this produces a bright matte deposit, sometimes referred to as milky. This deposit is extremely thin, and is of no commercial value. Increasing the current density changes this deposit to one which is bright, hard and lustrous, requiring little finishing after removing from the bath. With further increased current the deposit changes to a matte which, while dull, is capable of polishing with some labour. With the same current density at varying temperatures it is possible to produce the dull, hard deposit in the cold solution, this changing too with elevation of temperature to bright lustrous deposit, and at still higher temperature to the thin milky deposit. Combining these two factors it will be seen that there is a range within which the required lustrous deposit can be obtained, and this again varies with the composition of the solution. It is advisable, therefore, at the time of chromium plating to start with the solution recommended, and explore the conditions for obtaining the required deposit.

MANIPULATION.

As has been stated, the process of chromium plating calls for special methods of handling the work usually requiring plating. This is occasioned by (i) the high current density employed, (ii) the poor throwing power, and (iii) the large volume of gas generated.

The high current density demands special care in the size of suspension wire and their manner of contact. Wherever possible, these should be screwed or soldered. For lamp reflectors, rings and radiator shells, special racks of frames should be constructed, and arranged to give large contacts up to 75 or 80 per cent. of the circumference of circular parts, to guarantee uniformity of deposition. If the article cannot be racked, it will be necessary to move the suspension wire to avoid the marks due to the protective effect of the suspension wires. These wires should be of sufficient thickness, to enable them to carry the currents without undue heating. If heating occurs there is obvious waste of energy, and the current is being unnecessarily reduced.

The poor throwing power will call for the extended use of subsidiary anodes opposite recessed parts, and difficulties of plating will thus be overcome. In other cases shaped work can be best dealt with by the use of similarly shaped anodes, and the usual lead anode readily lends itself to this adaptation. Bent lead strips are very serviceable for this purpose. This can be introduced into the bath by auxiliary bars resting across the usual anode bars, but covered with insulating tape at points near possible contact with the cathode bars. For radiator shells the anodes can be thus conveniently made to follow the contour of the shell.

Again, holes in the work cause some trouble by reason of the gas deposited within them escaping, and thus curtailing deposition over a small area around them. It is convenient to fill up such holes with cork or wood bungs. For other purposes of insulation a paste made from red lead and glycerine are useful, while the points of first contact of slinging wires with the work may be advantageously covered with insulating tape to prevent undue deposition at these points, with

burning and loss of metal on other parts. Inside surfaces may be dealt with in much the same way as in silver-plating by the use of auxiliary anodes either of shaped lead or even iron wire, due care being taken to prevent short circuiting at possible points of contact.

Where a small portion of the surface has failed to receive a deposit the usual process of "doctoring" may subsequently be resorted to. The "doctor" may be made of iron wire covered with asbestos cotton, and connected to the positive rod. The chromium solution can therefore safely be used in this manner. In subsequent buffing, however, care must be taken to deal much gently with these parts

CHAPTER XIII

DEPOSITION OF TIN.

THERE are three different methods of coating brass and other metals with tin. By two of these methods a beautifully white film of tin is deposited, but not of sufficient thickness to be of a durable character. By the third method a deposit of required thickness may be obtained.

DEPOSITION BY DIPPING.

In order to do it successfully a saturated solution of cream of tartar is prepared with boiling water, into this solution small articles of brass or copper are placed between sheets of grain tin, and the liquid is boiled until the desired result is obtained. Ordinary brass pins are coated in this manner. The process of tinning articles of iron, however, is somewhat different. The solution itself is not the same as above but it is composed of the following —

Protochloride of tin	2½ grams
Ammonia alum	75 „
Distilled water	5 litres
Dissolve	

The ammonia alum referred as above can be composed of —

Ammonia	3 75	parts.
Alumina	11 34	„
Sulphuric acid	35.29	„
Water	49.62	„

When the solution of tin and alum has been brought to a boil, the iron articles, after being well cleaned and rinsed in water, are immersed in the liquid, when they quickly become coated with a delicately white film of a dead or matted appearance. In maintaining the strength of the bath small quantities of fused chloride of tin may be added from time to time. Articles which are to receive a more substantial coating of tin electrolytically may have a preliminary coating of tin in this way.

DEPOSITION BY CONTACT.

This is another method of coating performed without the help of battery. In this method the deposits of tin upon brass, copper, iron, or steel may be obtained from either of the following solutions by placing the articles, while in the hot bath, in contact with fragments of clean zinc, or with granulated zinc.

I.

Take equal weights of chloride of tin, cream of tartar and distilled water. Next dissolve the tin salt in one-third portion of the cold water, then heat the remaining quantity of water and dissolve in it the cream of tartar. Finally, mix the two solutions with stirring

II.

Chloride of tin (crystals)	6	parts
Pyrophosphate of sodium	60	„
Distilled water	3000	„

Dissolve.

N B —The above two solutions should be used hot and kept constantly in motion to ensure better result. The articles to be tinned are immersed in contact with fragments of zinc, the entire surface of which should be equal to one-thirtieth of that of the articles treated. They are kept in that state from one to three hours to obtain the required deposit. The strength of the bath should be maintained by adding in small quantities equal weights of fused chloride of tin and pyrophosphate of sodium from time to time.

ELECTRO-DEPOSITION.

This process is more reliable when deposits of considerable thickness are desired. There have been many different processes recommended and several of these have been worked upon a fairly extensive scale. For many purposes, this metal, when properly deposited by electrolysis, is very useful, but more especially for coating the insides of cast-iron culinary vessels, copper preserving pans, and articles of a similar description.

BATH SOLUTION.

The ideal bath solution may be prepared thus:—

Sodium carbonate	60	lbs.
Pearl ash	15	lbs.
Caustic potash	5	lbs.
Potassium cyanide	2	oz
Distilled water	75	gallons.
Zinc acetate	2	oz.
Peroxide of tin	16	lbs.

Dissolve; then filter the solution; next add and stir the mixture until all is dissolved, when the solution is ready for use.

In preparing articles for electro-tinning, they must be rendered perfectly clean, either by

scouring or dipping. Articles of cast iron may advantageously be first coppered in an alkaline coppering bath (See Copper-plating).

MAINTENANCE OF THE BATH.

In tinning articles by the electro-deposition it is found that the anodes do not dissolve in the bath in the same ratio as the deposit upon the cathode. Consequently the strength of the bath requires to be kept up by constant additions of salt of the metal to the solution while deposition is taking place. If this were not done, the bath would soon become exhausted, and cease to work altogether. To overcome this difficulty and to maintain the strength of the solution constant, arrange the depositing vessel, capable of receiving a tap, to this connect a vulcanised India-rubber tube, reaching nearly to the surface of the solution. Let this jar be nearly filled with concentrated solution of the tin salt employed. When the bath is being worked, let the tap be turned slightly, so that the concentrated solution may drip into the depositing bath.

The whole arrangement has already been shown in a foregoing figure

**THE ELECTROLYTIC METHOD OF RECOVERING TIN
FROM WASTE SCRAP.**

The high cost of tin, the enormous quantities required for tinned fruits and confectioneries and other industries, and the limited supplies in sight, lend peculiar interest to the possibilities of recovering tin from all forms of work that contain it.

Among the various processes suggested the following electrolytic method is by far the easiest and produces good results

This process consists more especially of "an improved method of treating cuttings, or waste, of tin plate in order to remove the metallic tin, but is also applicable to the separation of tin combined with metals, such as copper, zinc, or lead, or in combination with oxygen. The process consists first in making solutions of tin, preferably protochloride of tin, slightly acid, and afterwards extracting the tin in a metallic state by means of the simple apparatus used in the ordinary process of electrotyping." This consists in applying the "single cell" arrangement, as it is called, in which a plate of zinc is immersed in a porous cell filled with a saline solution, or acidulated

water, and which is placed in a larger vessel containing a solution of tin in lieu of the sulphate of copper, as in electrotyping. The zinc plate is connected by a suitable conducting wire to sheets of tin plate, placed round the porous cell, upon which plates the tin becomes deposited

“Supposing,” says the inventor, “cuttings of fresh tin plate are to be used, as often happens, I place them in vessels of material unaffected by the chemical agents employed, and keep them in movement by any convenient mechanical means, so as to prevent them from adhering together, since if left at rest they would remain adherent, and to a great extent escape the action of the acid liquids. These acid liquids may vary according to the character of the tin cuttings, or fragments, but I prefer to use a mixture of hydrochloric and nitric acids, in about the following proportions, namely, 250 to 300 kilo-grammes of hydrochloric acid, and 8 to 12 kilos, or even less, nitric acid. The vessels employed for this purpose may be constructed of stoneware, glass, slate, etc., and the mixed acids diluted

with about 1,000 litres of water, the acid liquor being heated by steam passing through coils, or otherwise, to the temperature of about 80 to 100 degrees. "While the process of solution is going on, a certain proportion of iron is also dissolved in removing the last particles of tin the fragments being removed when the further solution would cease to be economical." It is stated that the foregoing proportions of acids and water are sufficient to effect the separation of the tin from one ton of tin scrap, as, for example, preserved food cans.

Instead of nitric acid perchloride of iron may be used, by which the tin is effectually separated. The perchloride is preferably produced by dissolving 80 to 90 kilogrammes of peroxide of iron in 300 to 350 kilos of hydrochloric acid, this quantity being sufficient to separate the tin from a ton of tin plate, the quantity of water being the same as before, so as to completely cover the metal from which the tin is to be removed

CHAPTER XIV.

ELECTRO-GALVANISING.

THE deposition of zinc by the help of electric current has never attained the dignity of a really practical art. In the earlier periods many articles of iron were coated with zinc by this means, to protect them from rust, or oxidation, but it was soon found that the porous and granular nature of the deposit, instead of acting as a preservative from rust, greatly accelerated the action of moisture upon the underlying metal by setting up a galvanic current.

The process of coating iron with zinc by dipping it into a bath of molten zinc soon proved so superior to that of electro-zincing, that it became generally adopted to the entire exclusion of the latter. But there are other purposes to which this process of galvanising is applicable, and for which a good electro-deposit of zinc would be specially serviceable.

PREPARATION OF PLATING SOLUTION.

The most satisfactory result may be obtained by dissolving the best milled zinc in a strong solution of potassium cyanide, with the addition of liquid ammonia by means of a strong voltaic current. The process is as follows:

Dissolve $12\frac{1}{2}$ lbs. of potassium cyanide in 20 gallons of water; add 80 ounces, by measure, of strong liquid ammonia. Stir for some time. Then fill several large porous cells with this solution and place them upright in the vessel containing the bulk of the solution, the liquids in each vessel being at an equal height. Strips of copper are then connected by wires to the negative pole of a compound Bunsen battery of two or more cells, and these strips are immersed in the porous cells. A large anode of good milled zinc, previously cleaned, is now connected to the positive pole of the battery, and plate suspended in the larger vessel. The voltaic action is to be kept up until the zinc has become dissolved to the extent of about 60 ounces, or 3 ounces to each gallon of solution. To this solution add 80

ounces of carbonate of potash by dissolving it in portions of the solution at a time and returning the dissolved salt to the bath. Then remove the porous cells and allow the solution to rest for 12 hours. Lastly, transfer the clear liquor into another vessel, the last portions containing sediments being filtered into the bath.

PREPARATION OF THE WORK FOR BATH.

In making articles, such as iron, steel, etc suitable for deposition, they are first dipped for a short time in a hot potash bath, after which they are to be well rinsed. They are next steeped in acid pickle composed of sulphuric acid $\frac{1}{2}$ pound and water 1 gallon. As soon as the black coating of oxide yields to the touch the articles are removed and plunged into cold water; they are then taken out and rubbed with a hard brush with sand and water. If any oxide still adheres to the surface, the articles must be immersed in the pickle again and rubbed with a brush as before. This process may be repeated until the articles are quite cleaned. They are now well rinsed, and at once suspended in the zincing bath, in which

they should remain for a few minutes, then taken out and examined; and if any parts found to be uncoated or under-coated, these must be again well scoured, the article being finally brushed all over, again rinsed, and placed in the depositing bath, where they are allowed to remain until sufficiently coated. An energetic current from at least two Bunseu cells, where a dynamo-machine is not available, is necessary to obtain a good deposit. The articles may be rendered bright by means of the scratch brush, but large articles may be sufficiently brightened by means of sand and water, with the assistance of soap. When finished they should be dipped in hot water and dried by means of hot saw dust. The anodes should be of the best milled zinc, and well cleaned before using.

ZINCING SOLUTIONS.

For electro-deposition of zinc, solutions of the sulphate, ammonio-sulphate, chloride, and ammonio-chloride may be employed, as also alkaline solutions prepared by dissolving zinc oxide or carbonate in a solution of cyanide of potassium or caustic potash; the deposit from

either of these alkaline solutions is generally of very good quality, and if too strong a current is not employed, the deposited metal is usually very tough.

Another useful formula as described by Watt consists of a mixture of 1 part of oxide of zinc dissolved in 100 parts of distilled water, in which 10 parts of alum have been previously dissolved at the ordinary temperature. The current from a single battery cell is employed, and the anode surface should be about equal to that of the articles to be coated, when the deposition proceeds as easily as that of copper, and takes place with equal readiness upon any metal

DEPOSITION OF ZINC BY SIMPLE IMMERSION.

Iron articles may also be coated with zinc by simple immersion in the following manner:—A mixture is first made consisting of (by measure) hydrochloric acid 55 parts, sulphuric acid 5 parts, water 100 parts and glycerine 2 parts. The iron articles are first pickled in this mixture and then placed in a solution composed of carbonate of potash 1 part and water 10 parts. The articles are next to be immersed

from three to twelve hours in a mixture composed as follows:—Water 1000 parts, ammonium chloride 10 parts, potassium bitartrate 8 parts, chloride of tin 5 parts, zinc chloride 4 parts. The thickness of the deposit is regulated by the duration of the immersion.

TESTING THE DEPOSIT OF ZINC.

It is quite true to say that hitherto, very little attention has been paid by practitioners to the structure of zinc deposits in relation to their service as protectors of the underlying iron or steel. The testing of the deposit may be carried out both by mechanical and chemical tests.

MECHANICAL TESTS.

In mechanical tests the following four tests are recommended. These are:—

(a) *The saw test*: In this test, the plated article is placed in a vice, and sawn through with a back-saw.

(b) *The Hammer test*: In this test the plated article is struck glancing blows with a hammer having a 1 lb head.

(c) *The squeezing test*: Here, the article, where suitable, e g., a tube, is held in a vice,

and squeezed until the distance between the jaws of the vice is diminished by about 50 per cent.

(d) *The Grinding test*: In this test, the deposit is ground through by a dry emery wheel of some 6 inches diameter and rotating at about 1500 R.P.M. It is suggested that the saw test helps one to obtain an approximate idea of the brittleness and toughness of a deposit.

Nothing more is claimed for these tests than that they afford a fair estimate, for practical purposes, of the properties in general and of the adherence of a deposit, whether of zinc or other metal. These should be used in conjunction with other tests, among which may be mentioned the bending test. This, like the squeezing test, can be applied to such articles only as possess the requisite shape, e g., tubes, sheet, and the like. It consists in bending the article (holding it in a vice, if necessary) so that one part is bent over towards the other through a right angle at least, and examining the deposit on the surface of the bent portion for fractures.

CHEMICAL TESTS.

These require somewhat fuller treatment, as it is necessary to show clearly what each really indicates.

(1) *Copper Sulphate Test*—This consists in dipping the zinc-coated article in a saturated and neutral solution of copper sulphate for a certain period of time, (half or one second), taken as the unit, holding it, after removal from the sulphate, under a water tap giving a flow at full pressure, and noting how much dips can be given before a firmly adherent coat of copper becomes deposited upon the iron or steel

(2) *Sulphuric Acid Test*—This test consists in immersing the galvanised article in a 32 per cent solution of pure sulphuric acid. It can be used for more accurate work than that obtained by copper sulphate test; but it is suggested that its chief use in the workshop is that, by means of it, one can observe the uniformity of the thickness of the zinc deposit much more exactly than the other allows. When acid of the strength given is used, a stream of hydrogen-gas is evolved from the

surface of a galvanised article immersed in it. But as soon as the zinc is dissolved from any part of the surface, the evolution of gas ceases there. Thus one can easily tell where the deposit is thicker, and where it is thinner; and the cessation of the evolution of bubbles is so marked that small differences of thickness can be readily detected.

(3) *Caustic Soda-Test*—This test forms a very useful test of the porosity of a zinc coating. If a piece of zinc is placed in a strong solution of caustic soda, heated to about 100°C , no action is noticeable. If, now, the zinc is touched with a piece of iron, hydrogen is liberated in great volume from the iron. That is, iron, in contact with zinc in strong, hot, caustic soda is a seat for the formation of hydrogen. Hence, if a piece of galvanised iron free from pin-holes and cracks is so treated, no action is visible; if the iron is exposed, however, to even a minute degree, a fine stream of hydrogen bubbles will be seen arising from the surface. Small cracks in the zinc surface may easily be detected in the same way.

CHAPTER XV.

METAL COLOURING.

INTRODUCTION.

SUBSEQUENT to electro-deposition many metals are subjected to chemical processes by which they acquire relatively thin films of compounds which, in addition to their pleasing colour, are more permanent in air than the metals themselves

Reference has already been made under the finishing process to the permanence acquired by metals owing to the formation of thin and stable films of oxides. A suggestion, therefore, forces itself into notice that the designed production of such oxide films might play an important part in the longer preservation of metals exposed to corrosive conditions

If this is possible with oxides it might be equally attainable and effective with films of sulphides, and the processes of forming films of metallic compounds for the dual purpose of

decoration and protection are generally known as metal colouring.

GENERAL METHODS.

These films are producible by at least four entirely different ways:—

(1) Mechanical methods comprising those similar to painting and including spraying and dipping processes.

(2) Thermal methods which employ an elevation of temperature to bring about the desired chemical change.

(3) Chemical methods, which are the most largely used, whereby the metals are immersed in appropriate chemical solutions in order to acquire these films by chemical action.

(4) Electrolytic methods, when usually the metal is made the anode in the solution and is then oxidised.

PROPERTIES OF CHEMICAL FILMS

Apart from pleasing colour, the chemical films must possess properties which will make for permanence.

In a general way it may be taken for granted that the compounds formed are less

active than the metals from which they have been produced. Similarly, the removal of oxide films during the process of pickling is not infrequently more or less mechanical; the porous oxide films admit the acid to the metal beneath, which becomes attacked with surface solution, whereby the film of oxide drops from the corroding surface of the metal.

They should then be non-hygroscopic, that is, they should not attract atmospheric moisture.

GENERAL PROCEDURE

The preparation of metallic surfaces prior to metal colouring necessitates the same degree of care as with electrodeposition, possibly even more so because the colouring solutions employed are almost entirely free from any substance with cleansing properties. Many of the solutions are practically neutral. Absolute chemical cleanliness may be regarded as essential where successful results are not at first obtained, the complete removal of the imperfect colour film is of the utmost importance. The exact matching of colours and shades is difficult in the case of small scale operations.

On the larger scale uniform results are the much more frequent rule, there being greater control over the composition of the solution, and its temperature, both important factors.

Different effects again may be obtained by the use of different types of surface. These may be bright by polishing, or dead by dipping, sand-blasting, or by the application of the colouring process directly on to the matt surface obtained. Again, variations of effects are possible by the light scratch-brushing of the somewhat dull colours at first produced.

A few typical examples will now be referred to, a much wider range being available from other works dealing more exclusively with this phase of decorative metal work.

COLOURING OF COPPER.

A wide range of colour and shade is effectively obtained on copper by the use of a number of solutions, the chief constituent of which is one of the soluble sulphides including those of sodium, potassium, barium, and ammonium. With different concentrations, temperatures and times of exposure, the colours may vary

from the lightest brown to black, and still further variations are possible according to whether the copper surface is smooth or matt, the latter surface generally yielding the darker colour.

These colours also lend themselves to relief with still further possible variations of effect. The processes are widely used.

COPPER OXIDIZE

A typical solution is—

Liver of sulphur	2 oz.
Ammonium chloride	2 lbs.
Water	1 gallon.

The solution is used cold. If warmed a weaker solution will serve the purpose better.

FLORENTINE BRONZE

This very pleasing effect is produced by the application of a paste composed of red oxide of iron and black lead and drying at 100°C for about half an hour. When dry the dried paste, i.e., dry powder is then removed with a stiff bristle brush. Darker shades are obtained at a higher temperature. The electrolyte copper will produce good result in this case.

STEEL BRONZE.

A typical solution is—

Arsenious oxide	10 oz.
Copper sulphate	10 oz.
Ammonium chloride	2 oz.
Hydrochloric acid	1 gallon.

The oxide of arsenic readily dissolves in the warmed acid, the other materials being subsequently added. The solution at 120°F gives a quick result, but in cold solution the simple deposition of arsenic takes place more slowly.

COLOUR OF BRASS.

In view of the fact that traces of impurity in copper profoundly influence the colour effects chemically developed, it becomes quite impossible to predict with certainty the results of the same solutions on brass.

VARIOUS COLOURS.

Solution—

Sodium thiosulphate	12 oz.
Lead acetate	8 oz.
Water	1 gallon.

The salts are added together to the water and raised to 180°F. Clean brass acquires in

this solution the following succession of colours: pale gold, dark gold, orange, brown, deep blue and finally to steel grey. Careful manipulation will succeed in arresting the process at any desired shade.

The succession of colours appears to be due to the reflection of light from the metal below, through the increasingly thicker film of deposited lead sulphide. When the film becomes appreciably thick, the observed colour is that of the opaque film. The colours are rendered much more permanent by lacquering.

BLACK ON BRASS

Several solutions are available for this effect. They usually comprise ammoniacal solutions of copper salts such as—

Copper sulphate	4 oz.
Water	1 gallon.
Ammonia solution sp. gr 0.880	q s.

The copper salt is dissolved in a part of the water. Ammonia is added until the green hydroxide of copper first formed is nearly all dissolved. This solution gives a quick result when used hot. The action is slower when cold.

COLOURING OF SILVER.

While silver is not susceptible to direct combination with oxygen, it readily discolours under ordinary atmospheric conditions. This is mainly due to the presence of sulphuretted hydrogen, which produces thin films of silver sulphide of various shades.

A very satisfactory method of oxidising silver involves its immersion in a solution of platinum chloride.

METALLOCHROMES.

These purely decoration effects are produced on polished metals, usually iron or nickel, by making them anode in a solution of lead salt when, by electrolysis, thin films of peroxide of lead are deposited upon them giving rise to what may be called rainbow effects due to interference.

A suitable solution for this purpose is—

Litharge	62.5	grms.
Caustic potash	100	"
Water	1	litre.

The polished plate is made the anode and the cathode is provided by a copper or other

wire held with its end facing the plate and close to it. Lead peroxide is formed opposite to the cathode wire, the deposit spreading from this initial centre and decreasing in thickness with distance.

It is this varying thickness which breaks up the light as it passes through and is reflected from the polished surface below. The ornamental character of the effects may be increased by shaping the cathode wire and varying its distance from the polished anode. The results are striking, but cannot be said to be of large application.*

* Summarised from Electro-plating by Samuel Field and A Dudley Weill

APPENDIX I.

Weights & Measurements

24 Grains	=	1 Pennyweight (dwt.)
24 Pennyweights	=	1 Ounce (troy)
12 Ounces	=	1 Pound (troy)
180 Grains	=	1 tola
11½ Grains	=	1 anna
15 Grains	=	1 gramme
3.1/5 Grains	=	1 carat
8 Pints	=	1 gallon = 160 fluid ounce

Electrical Measurements.

1 Coulomb	=	1 amp-second
3600 Coulombs	=	1 amp-hour.
1 Watt	=	1 volt-amp.
740 Watts	=	1 horse-power
1 Killowatt-hour	=	1000 Watt-hours
	=	1 Unit (B O T)
	=	1½ horse-power.

Relation of Metallic Deposits with Current.

1 Coulomb deposits	0 000329	gr	of copper per sec
1 " "	0 00118	"	silver " "
1 amp "	1 186	"	copper per hour.
1 " "	4 026	"	silver " "
96500 coulombs or 26 8 amp-hours	} deposit one gramme } equivalent of any metal } per hour		

APPENDIX II.

Volt and Temperature

	Volt	Temperature
Gold	2—6	100°—140°F
Silver	$\frac{3}{4}$ —1	—
Copper-Acid	1—2	70°—100°F
Copper-Cyanide	2—3	62°—160°F
Nickel	1—2	62°—100°F
Chromium	2—3	113°—122°F

APPENDIX III.

Amount of Metal deposited in one amp-hour.

Metal	Type of Bath	Grains	Tola & Annas	Grams
Gold	Cyanide	113 50	10 4/45	2 364
"	Chloride	—	—	2 436
Copper	Cyanide	36 60	3 28	2 360
"	Sulphate	18 30	1 64	1 180
Silver	Cyanide	62 106	5 511	4 024
Nickel	Cyanide	16 89	1 57	1 098

185 8 Amp current will deposit in one hour 1 lb of gold

382 5 " " copper

112 7 " " silver

414 8 " " nickel

In the above manner if we increase the time the am pereage will be reduced proportionately

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